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AMERICAN SCIENCE SERIES

ZOOLOGY

FOR

HIGH SCHOOLS AND COLLEGES

BY

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SECOND EDITION, REVISED

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PREFACE.

THIS book is designed to be used quite as much in the laboratory or with specimens in hand, as in the class-room. If Zoology is to be studied as a mental discipline, or even if the student desires simply to get at a genuine knowledge, at first hand, of the structure of the leading types of animal life, he must examine living animals, watch their movements and habits, and finally dissect them, as well as study their mode of growth before and after leaving the egg or the parent, as the case may be. But the young student in a few weeks' study in the laboratory cannot learn all the principles of the science. Hence, he needs a teacher, a guide, or at least a manual of instruction. This work is an expansion of a course of lectures for college students, but has been prepared to suit the wants of the general reader who would obtain some idea of the principles of the science as generally accepted by advanced zoologists, in order that he may understand the philosophical discussions and writings relating to modern doctrines of biology, especially the law of evolution and the relations between animals and their surroundings.

The book has been prepared, so far as possible, on the inductive method. The student is presented first with the facts; is led to a thorough study of a few typical forms, taught to compare these with others, and finally led to the principles or inductions growing out of the facts. He has not been assailed with a number of definitions or diagnoses applicable to the entire group to which the type may belong before he has learned something about the animals typical of the order or class; but these are placed after a description of one or a few examples of the group to which they may belong. The simplest, most elementary forms are first noticed, beginning with the Protozoa and ending with the Vertebrates. In working up from the simplest forms to those more complex, it is believed that this is the more logical and philosophical method, and that in this way the beginner in the science can better appreciate the gradual unfolding of the lines of animal forms which converge toward his own species, the flower and synthesis of organic life. Still the learner is advised to begin his work by a study of the first part of Chapter VIII., on Vertebrates, and to master, with a specimen in hand, the description of the frog, in order that he may have a standard of comparison, a point of departure, from which to survey the lower forms.

Particular attention has been given to the development of animals, as this subject has been usually neglected in such manuals. Some original matter is introduced into the book; a new classification of the Crustacea is proposed, the orders being grouped into the subclasses *Neocarida* and *Palæocarida.* Most of the anatomical descriptions and drawings have been made expressly for this book, and here the author wishes to acknowledge the essential aid rendered by Dr. C. S. Minot, who has prepared the drawings and descriptions of the fish, frog, snake, turtle, pigeon, and cat.

In compiling the book, the author has freely used the larger works of Gegenbaur, Huxley, Peters and Carus, Claus, Rolleston, and others, whose works are enumerated at the end of the volume, and in many cases he has paraphrased or even adopted the author's language *verbatim* when it has suited his purpose. Besides these general works many monographs and articles have been drawn upon.

In order to secure a greater accuracy of statement, and to render the work more authoritative as a manual of Zoology, the author has submitted the manuscript of certain chapters to naturalists distinguished by their special knowledge of certain groups. The manuscript of the sponges has been read by Professor A. Hyatt; of the worms and Mollusca, by Dr. Charles S. Minot; of the Echinoderms, by Mr. Walter Faxon; of the Crustacea, by Mr. J. S. Kingsley. Proofs of the part relating to the fishes have been revised by Professor T. Gill, whose classification as given in his "Arrangement of the Families of Fishes," has been closely followed, his definitions having been adopted often word for word. The manuscript of the Batrachians and Reptiles has been read by Professor E. D. Cope, whose classification, given in his "Check-List of North American Batrachia and Reptilia," has been adopted. Proofs of the part on birds have been read by Dr. Elliott Coues, U.S.A., whose admirable "Key to the Birds of North America" has been freely used, the author's words having been often adopted without quotation-marks. Dr. Coues has also revised the proofs of the pages referring to the Mammals. To the friendly aid of all these gentlemen the author is deeply indebted.

As to the illustrations, which have been liberally provided by the publishers, a fair proportion are original. The full-page engravings of the anatomy of the typical Vertebrates have been drawn expressly for this work by Dr. C. S. Minot; a number have been prepared by Mr. J. S. Kingsley; Prof. W. K. Brooks has kindly contributed the drawing of the nervous system and otocyst of the clam, and a few of the sketches are by the author.

The publishers are indebted to Prof. F. V. Hayden for illustrations kindly loaned from the Reports of the U.S. Geological Survey of the Territories; a few have been loaned by Prof. S. F. Baird, U.S. Commissioner of Fish and Fisheries, and the members of the U.S. Entomological Commission; a number have been loaned by the Peabody Academy of Science, Salem, Mass.; by the publishers of the *American Naturalist*, and by the Boston Society of Natural History, while forty of the cuts of birds have been electrotyped from the originals of Coues' Key, and Tenney's Zoology.

Measurements are usually given in the metric system; in such cases the approximate equivalent in inches and fractions of an inch being added in parenthesis.

Should this manual aid in the work of education, stimulate students to test the statements presented in it by personal observations, and thus elicit some degree of the independence and self-reliance characteristic of the original investigator, and also lead them to entertain broad views in biology, and to sympathize with the more advanced and more natural ideas now taught by the leading biologists of our time, the author will feel more than repaid.

BROWN UNIVERSITY,
Providence, R. I., October 25, 1879.

PREFACE TO THE SECOND EDITION.

A NUMBER of changes have been made since the first edition, consisting either of the correction of errors, or the insertion of facts new to science since the book was written. Figures of the opossum and its marsupial bone have been inserted on p. 575, and improved illustrations have taken the place of Figs. 400 and 492. The author would be thankful for the communication of additional errata, and for suggestions from teachers tending towards the improvement of the book; and here acknowledges, with thanks, kind aid from several naturalists in revising the first edition.

July, 1880.

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ZOOLOGY.

INTRODUCTION.

Definition of Zoology.—That science which treats of living beings is called *Biology* (*βίος*, life; *λόγος*, discourse). It is divided into *Botany*, which relates to plants, and *Zoology* (*ζῶον*, animal; *λόγος*, discourse), the science treating of animals.

It is difficult to define what an animal is as distinguished from a plant, when we consider the simplest forms of either kingdom, for it is impossible to draw hard and fast lines in nature. In defining the limits between the animal and vegetable kingdoms, our ordinary conception of what a plant or an animal is will be of little use in dealing with the lowest forms of either kingdom. A horse, fish, or worm differs from an elm tree, a lily, or a fern in having organs of sight, of hearing, of smell, of locomotion, and special organs of digestion, circulation, and respiration, but these plants also take in and absorb food, have a circulation of sap, respire through their leaves, and some plants are mechanically sensitive, while others are endowed with motion—certain low plants such as diatoms, etc., having this power. In plants, the assimilation of food goes on all over the organism, the transfer of the sap is not confined to any one portion or set of organs as such. It is always easy to distinguish one of the higher plants from one of the higher animals. But when we descend to animals like the sea-anemones and coral-polyps which were called Zoophytes from their general resemblance to flowers, so striking is the external similarity between the two kinds of organisms that the early observers regarded them as "animal flowers;" and in consequence of the confused notions originally held in regard to them the term Zoophytes has been perpetuated in works on systematic zoology. Even at the present day the compound Hydroids, such as the *Sertularia*, are gathered and pressed as sea-mosses by many persons who are unobservant of their peculiarities, and unaware of the complicated anatomy of the little animals filling the different leaf-like cells. Sponges until a very late day were regarded by our leading zoologists as plants. The most accomplished naturalists, however, find it impossible to separate by any definite lines the lowest animals and plants. So-called plants, as *Bacterium*, and so-called animals, as *Protamœba*, or certain monads, which are simple specks of protoplasm, without genuine organs, may be referred to either kingdom; and, indeed, a number of naturalists, notably Haeckel, relegate to a neutral kingdom (the *Protista*) certain lowest plants and animals. Even the germs (*zoospores*) of monads like *Uvella* (Fig. 1), and those of other flagellate infusoria, may be mistaken for the spores of plants; indeed, the active flagellated spores of plants were described as infusoria by Ehrenberg; and there are certain so-called flagellate infusoria so much like low plants (such as the red snow, or *Protococcus*), in the form, deportment, mode of reproduction, and appearance of the spores, that even now it is possible that certain organisms placed among them are plants. It is only by a study of the connecting links between these lowest organisms leading up to what are undoubted animals or plants that we are enabled to refer these beings to their proper kingdom.

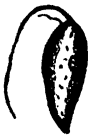

Fig. 1.—Uvella, a flagellate infusorian, or monad, with two large cilia called flagella. Greatly magnified.

As a rule, plants have no special organs of digestion or circulation, and nothing approaching to a nervous system. Most plants absorb inorganic food, such as carbonic acid gas, water, nitrate of ammonia, and some phosphates, silica, etc.; all of these substances being taken up in minute quantities. Low fungi live on dead animal matter, and promote the process of putrefaction and decay, but the food of these organisms is inorganic particles. The slime-moulds called *Myxomycetes,* however, envelop the plant or low animals, much as an *Amœba* throws itself around some living plant and absorbs its protoplasm; but *Myxomycetes,* in their manner of taking food, are an exception to other moulds. The lowest animals swallow other living animals whole or in pieces; certain forms like *Amœba* (Fig. 2) bore into minute algæ and absorb their protoplasm; others engulf silicious-shelled plants (diatoms) absorbing their protoplasm. No animal swallows silica, lime, ammonia, or any of the phosphates as food. On the other hand, plants manufacture or produce from inorganic matter starch, sugar and nitrogenous substances which constitute the food of animals. During assimilation, plants absorb carbonic acid, and in sunlight exhale oxygen; during growth and work they, like animals, consume oxygen and exhale carbonic acid.

Fig. 2.—Amœba, a Protozoan. The right-hand figure shows three pseudopodia on the right side; in the two other figures the pseudopodia are withdrawn in the body-mass.

Animals move and have special organs of locomotion; few plants move, though some climb, and minute forms have thread-like processes or vibratile lashes (cilia) resembling the flagella of monads, and flowers open and shut, but these motions of the higher plants are purely mechanical, and not performed by special organs controlled by nerves. The mode of reproduction of plants and animals, however, is fundamentally identical, and in this respect the two kingdoms unite more closely than in any other. Plants also, like animals, are formed of cells, the latter in the higher forms combined into tissues.

As the lowest plants and animals are scarcely distinguishable, it is probable that plants and animals first appeared contemporaneously; and while plants are generally said to form the basis of animal life, this is only partially true; a large number of fungi are dependent on decaying animal matter; and most of the *Protozoa* live on animal food, as do a large proportion of the higher animals. The two kingdoms supplement each other, are mutually dependent, and probably appeared simultaneously in the beginning of things. It should be observed, however, that the animal kingdom overtops the vegetable kingdom, culminating in man.

In speaking as we have of low animals and high animals, we are comparing very unequal quantities; the distance between monad and man is well-nigh infinite. But there is a series or chain, sometimes broken and often with lost links, connecting the extremes ; and as there are wide differences in form, so there are great extremes in the organs and degree of complication of function of the simple as compared with the more complex forms. The improvised stomach of an *Amœba* is not comparable with the stomach of an hydra, nor is the stomach of the latter creature with that of a horse ; there is a gradual perfection and elaboration or specialization of the stomach as we ascend in the animal series. So it is with organs of locomotion ; the pseudopods and cilia of the Protozoans are replaced in the star-fishes and worms by hollow tentacles or various fleshy soft appendages ; in crabs and insects by stiff, jointed limbs, with different leverage systems ; and these are replaced in vertebrates by genuine limbs supported by bones. A comparative view of the origin and structure of organs succeeds in this book the systematic account of the animals themselves.

We thus see that the organs of the higher animals are merely modifications of organs often having the same general functions as in the lower animals ; the lower or simpler have preceded in geological history the higher or more specialized forms, and thus we are, in ascending the animal series, going from the simple to the complex. For this reason the plan of this work has been to lead the student from the simpler forms of animal life to the more complex ; and though the vertebrate animals, such as fishes and dogs, are more familiar and interesting to us, the serious student of zoology will feel that it is more logical and better in the end to study the animal world in the order in which the different forms have appeared—as we believe, through the orderly operations of physical and biological laws, under the guidance of an Infinite Intelligence—a Creator whose modes of working are revealed to us in what we call the laws or processes of nature.

Zoology is subdivided thus :

Zoology.
- Morphology or gross Anatomy, and minute Anatomy (Histology).
- Physiology and Psychology.
- Reproduction and Embryology.
- Systematic Zoology or Classification.
- Palæontology.
- Zoogeography.

Morphology.—In order to properly understand Zoology, one should first study Morphology—*i.e.*, the general structure of animals. The student should first thoroughly acquaint himself with the anatomy of a vertebrate animal, such as a frog, as compared with that of a toad or salamander. The examination and comparison of the organs of animals belonging to distinct groups, is called Comparative Anatomy. The study of Morphology also includes the relation of the different organs to one another, and of all to the walls of the body. Finally, we need also to study the composition of the tissues of the different organs ; each kind of tissue being formed of different kinds of elements or cells. This department of Comparative Anatomy is called *Histology* (Greek, *ἱστός*, web or tissue ; *λόγος*, discourse). It treats of the cell, and the combination of cells into germ-layers, tissues, and organs.

The Cell.—The primary elements of the bodies of animals are called cells. They are microscopic portions of protoplasm either with or without a wall. Protoplasm largely consists of protein, which is a complex compound of carbon, hydrogen, oxygen, and nitrogen, associated with a large proportion of water. Cells are originally more or less spherical sacs, and the protoplasm forming the cell-mass is the dynamic part of the cell. The protoplasm of animal as well as vegetable cells, the protoplasm of eggs and of the cells forming the different tissues of the animal body, as well as the entire Amœba or monad, is all alike, being perfectly homogeneous to the chemist or microscopist of our day. Yet potentially the protoplasm of different cells exerts widely different forces and capabilities. An egg-cell becomes a man, whose brain-cells are the medium of the intellectual power which enables him to write the history of his own species, and to be the historian of the forms of life which stand below him. The cell is the morphological unit of the organic world. With cells the biologist can in the imagination reconstruct the vegetable and animal worlds.

The primitive form of a cell, when without a *nucleus* or *nucleolus*, is called a *cytode;* genuine cells have a nucleus, the latter containing a nucleolus. Animals composed of but a single cell, such as the *Amœba* or an Infusorian, are said to be *unicellular.* Cells grow by absorbing cell-food—*i.e.*, by the assimilation of matter from without, and this matter may be in masses of considerable size when seen under the microscope. Cells multiply by self-division. The egg-cell undergoes division of the yolk into two, four, eight, and afterward many cells; the cells thus formed become arranged into two layers or sets called germ-layers. The outer is called the *ectoderm* and the inner the *endoderm.* A third germ-layer arises between them, called the *mesoderm* or middle germ-layer. From these germ-layers, or cell-layers, the *tissues* of the body are formed, such as muscle, bone, nerve, and glandular tissue. These tissues form *organs,* hence animals (as well as plants) are called *organisms,* because they have certain parts formed of a particular kind of tissue set apart for the performance of a special sort of work or physiological labor. This separation of parts for particular or special functions is called *differentiation;* and the highest animals are those whose bodies are most differentiated, while the lowest are those whose bodies are least differentiated; hence *high* animals are *specialized,* and, on the other hand, *low* animals are *simple.* Thus dif-

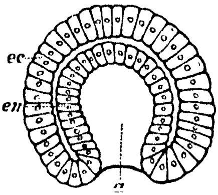

Fig. 3.—Germ of Sagitta. *ec*, ectoderm; *en*, endoderm; both layers formed of nucleated cells.

ferentiation of organs involves the division of physiological labor.

Tissues.—Of the different kinds of tissues there is, first, *epithelial* tissue (Fig. 4) consisting of cells with a nucleus and nucleolus, and placed side by side, forming a layer. All the organs develop originally from *epithelium*, which is the primitive cell-structure and forms the tissues of the germ-layers. Epithelial cells form the skin of animals, and also the lining of the digestive canal. The cells of the latter may, as in sponges, bear a general resemblance to a flagellate infusorian, as *Codosiga*, or they may each bear many hairs, called *cilia*, which by their constant motion maintain currents of the fluids passing over the surface of the epithelium. The tissue forming glands is simply modified epithelium.

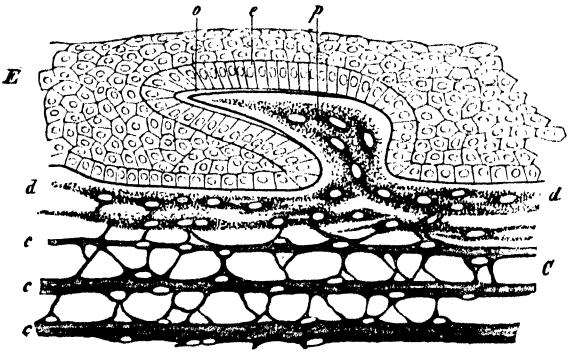

Fig. 4.—Vertical section through the skin of an embryonic shark, showing at *E* the epithelial cells, forming pavement epithelium; and at *e*, columnar epithelium.—After Gegenbaur.

Connective tissue is formed by isolated rounded or elongated cells with wide spaces between them filled with a gelatinous fluid or protoplasm, and occurs between muscles, etc. This tissue forms in the vertebrates the "notochord" —*i.e.*, a rod supporting the bodies of vertebrate embryos. *Gelatinous tissue* is a variety of connective tissue found in the umbrella of jelly-fishes (*Aurelia*, etc.). *Fibrous* and *elastic tissue* are also varieties of connective tissue.

Cartilaginous tissue is characterized by cells situated in a still firmer intercellular substance; and when the intercellular substance becomes combined with salts of lime forming bone, we have *bony tissue.*

The blood-corpuscles originate from the mesoderm as independent cells floating in the circulating fluid, the blood-cells being formed contemporaneously with the walls of the vessels enclosing the blood. In the invertebrates the blood-cells are either strikingly like the *Amœba* in appearance, or are oval, but still capable of changing their form. Thus blood-corpuscles arise like other tissues, except that the blood-cells are free.

Fig. 5.—Striated muscular fibrilla of a water beetle.—After Minot.

Muscular tissue is also composed of cells, which are at first nucleated and afterward lose their nuclei. From being at first oval, the cells finally become elongated and more or less spindle-shaped, forming fibres; these unite into bundles forming muscles. Each fibre is ensheathed in a membrane called *sarcolemma.* Muscular fibres may be simple or striated (Fig. 5). The contractility of muscles is due to the contractility of the protoplasm originating in the cells forming the fibres.

Nervous tissue is made up of nerve-cells and fibres proceeding from them; the former constituting the centres of nervous force, and usually massed together, forming a *ganglion* or nerve-centre from which nerve-fibres pass to the periphery and extremities of the body, and serve as conductors of nerve-force (Fig. 6).

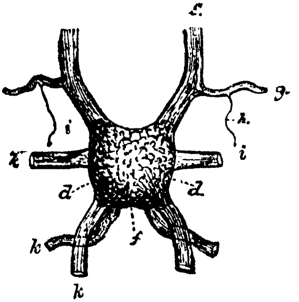

Fig. 6.—A ganglion in the clam, with nerves (*e*, *g*, *k*) proceeding from it.

Organs and their Functions.—Having considered the different kinds of cells and the tissues they form, we may now consider the origin of organs and their functions. The Protamœba may be considered as an organless being. In *Amœba* (Fig. 11) we first meet with a specialized portion of the body, set apart for the performance of a special function.

Such is the nucleus ; so that Amœba is a genuine organism. Ascending to the flagellate Infusoria (Fig. 1), we have the flagella developed as external, permanent organs of locomotion. In the Hydra (Fig. 36) the tentacles are organs whose functions are generalized. In the worms we have organs arranged in pairs on each side of the body, and in general among the higher invertebrates, especially the crustaceans and insects, and markedly in the vertebrates, we have the bilateral symmetry of the body still farther emphasized in the nature and distribution of the appendages.

Of the internal organs of the body, the most important is the digestive cavity, which is at first simple and primitive in the *gastrula* or embryo of all many-celled animals, and as we ascend in the animal series we witness its gradual specialization, the digestive tract being differentiated into distinct portions (*i.e.*, the œsophagus, stomach, and intestine), each with separate functions and with organs of respiration, digestion, secretion, and excretion set apart as offshoots or outgrowths from the main alimentary tract. In like manner the skeleton is at first simple and afterward is extended into the different organs, the various parts of the appendicular skeleton corresponding to the increased flexibility and diversified leverage power ; so that limbs become subdivided into joints, and these joints still further subdivided as we go from the points of attachment to the periphery or extremities, as seen in the tendency to an irrelative repetition of joints in the limbs and feelers of crustaceans and insects, and the digits of the lower vertebrates.

Correlation of Organs.—Cuvier established this principle, showing that there is a close relation between the forms of the hard and soft parts of the body, together with the functions they perform, and the habits of the animal. For example, in a cat, sharp teeth for eating flesh, sharp curved claws for seizing smaller animals, and great muscular activity coexist with a stomach fitted for the digestion of animal rather than vegetable food. So in the ox, broad grinding teeth for triturating grass, cloven hoofs that give a broad support in soft ground, and a several-chambered stomach coexist with the habits and instincts of a ruminant. Thus the form of the teeth presupposes either a ruminant or carnivore. Hence this prime law of comparative anatomy led to the establishment by Cuvier of the fundamental laws of palæontology, by which the comparative anatomist is enabled to restore from isolated teeth or bones the probable form of the original possessor. Of course the more perfect the series of bones and teeth, or the more complete the remains of insects or mollusks, the more perfect will be our knowledge, and the less room will there be for error in restoring extinct animals.

Adaptation.—An organ with a certain normal use or function may be adapted, in consequence of a change in the habits of the animal, to another use than the original one. To take an extreme case, the *Anabas*, or climbing fish, may use its fins to aid it in ascending trees. On the other hand, by disuse organs become aborted or rudimentary. The teeth of the whalebone whale are rudimentary in the young, and are replaced by whalebone, which is more useful to the animal; the eyes of the blind-fish are rudimentary, functionless. Those of certain cave-insects are entirely wanting, being lost through disuse, owing to a change of life from the light, outer world to totally dark caverns, and the consequent disuse of their eyes. Nature is economical. Every thing that is not of use as a rule disappears. It would be a waste of material to nourish and care for an organ in a cave-animal, or a parasitic insect or crustacean, which would be of no use to the animal. On the other hand, if the leg or tail of a newt is snipped off by some rapacious fish, it grows out again.

Moreover, the animal organism is far more pliable than is generally supposed. Not only is nature continually repairing wounds and waste, not only is the body being continually made over again, but certain animals undergo a change of form, either generally or in particular parts. If the environment is unchanged, the animal remains true to its species. The dogma of the invariability or stability of species is a fallacy. Change the climate, moisture or dryness, the nature of the soil; introduce the natural enemies of the animal or remove them; destroy the balance of nature, in other words, and the organism changes. The plants and animals of the mummies and monuments of Egypt are probably the same as those now living in that country, because the climate and soil have remained the same.

The assemblages of life that have successively peopled the surface of the earth, and which are geological time-marks, have probably become extinct because they could not adapt themselves to more or less rapid oscillations of continents and islands, to consequent changes of climate and the incoming of destructive types of life. This probably accounts for the origin, culmination, and extinction of different types of life. The earth has been, and still is, in a state of unstable equilibrium. Organic life has been and is even now, in a degree, being constantly readjusted in harmony with these changes of the earth's surface and climate. Thus this adaptation of organs to their uses, of animals to their environment, the laws controlling the origination of new forms of life and the extinction of those which have acted their part and are no longer of service in the economy of nature, is part of the general course of nature, and evinces the Infinite Wisdom and Intelligence pervading and continually operating in the universe.*

Coupled with *variability* is the law of *inheritance* and *transmission* of variable parts, and the habits thus induced by the variation of parts. It should be observed that the portions which vary most are the peripheral parts—*i.e.*, fingers and toes, tentacles and antennæ, the skin and scales and hair ; it is by modifications and differences brought about in those parts most used by animals that the multitudes of specific forms have resulted. There is, as Darwin states, a general tendency of organisms to vary ; the laws accounting for this tendency to vary have yet to be formulated ; though the attempts of Lamarck in this direction laid the way for the discovery and application of the fundamental laws of evolution. On the other hand, pure Darwinism—viz., natural selection—accounts rather for the *preservation* than the *origination* of the forms of life.

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* That animals and plants are self-evolved, that the world has made itself, and that all is the result of so-called physical and biological laws operating from within outward, is as inconceivable as the mediæval dogma that animals and plants and the earth they inhabit were made in the twinkling of an eye. See the concluding chapter on Evolution.

Analogy and Homology.—When we study the Invertebrates alone we see that it is often easy to trace a general identity in form between the more important parts. We notice that the under lip of a worm is comparable to the foot of a mollusk, though the functions of these parts may be quite unlike; these are therefore examples of a general identity in structure or *homology* between two organs. A closer homology implies a more apparent identity of form, as seen in the resemblance in structure of the fore-limbs of a whale and a seal, or the pectoral fins of fishes and the fore-arms of man.

Analogy implies a dissimilarity of structure of two organs with identity in use, as the wing of an insect and of a bird; the leg of an insect and the leg of a frog; the gill of a worm and the gill of a fish.

Homology implies blood-relationship; analogy repudiates any common origin of the organs, however physiologically alike. The most general homologies are those existing in organs belonging to animals of different branches; the most special between those of the same orders and minor groups. Thus it is fundamentally a question of near or remote consanguinity.

Physiology treats of the mode in which organs do their work; or, in other words, of the *functions* of different organs. Thus the hand grasps, the fins of a fish are its swimming organs; the function of the nose is to smell, of the liver to secrete bile, of the ovary to secrete protoplasm which forms eggs.

Psychology is the study of the instincts and reasoning powers of animals; how they act when certain parts are irritated; so that while this term is generally applied to man alone, Comparative Psychology deals both with the simplest automatic acts and the whole series of psychic processes—from those exercised by the Protozoans, such as *Amœba,* up to the complicated instinctive and rational acts of man.

Reproduction.—The simplest form of reproduction is cell-division, one cell budding or separating from another. This mode of growth is called *self-division* or *fission.* Where one cell separates from another, the separating part being smaller than the original cell, or where a number of cells separate or bud out from a many-celled animal, such as a *Hydra,* the process is called *gemmation.* A third mode of reproduction is sexual, the sperm-cell of the male coalescing with the nucleus of the egg ; the commingling of the protoplasm of the two nuclei resulting in a series of events leading to the formation of a germ or embryo.

Embryology is, strictly speaking, a study of the development of animals from the beginning of life of the egg up to the time the animal leaves the egg or the body of the parent —namely, up to the time when it begins to shift for itself ; but the term embryology may also be applied to the growing animal from the egg to the adult condition. Many of the lower animals undergo a *metamorphosis,* suddenly assuming changes in form, accompanied by changes in habits and surroundings ; so that at different times it is, so to speak, a different animal. For example, the caterpillar lives on solid food, crawls on the ground, and has a worm-like form ; it changes to a chrysalis or pupa, lying quiescent, taking no food ; then it changes to a butterfly and flies in the air, either taking no food or sipping the nectar of flowers : in all these three stages it is virtually different animals with different surroundings. Many animals besides insects have a metamorphosis, and their young are called larvæ ; thus there are larval polyps, larval star-fish, larval worms—these larvæ often differing remarkably in form, habits, and in their environment or surroundings, as compared with the mature or adult forms.

Classification.—After thoroughly studying a single animal, its external form, how it acts when alive, its external and internal anatomy after death, and the development of other individuals of its own species, the student is then ready to study the classification of animals.

The best method of studying classification, or Systematic Zoology, is to make an exhaûstive examination of one animal, and then to study in the same thorough manner an allied form, and, finally, to compare the two. For example, take a frog and compare it with a toad, and then with a newt, or a land salamander; thus, by a study of the different types of Batrachians, one may arrive at a knowledge of the affinities of the different species of the class. The methods of research are, then, *observation* and *comparison*. The best and most philosophic observers are those who compare most. Then, passing on to other animals, the student will place in one group animals that are alike. He will find that many agree in certain general characters common to all. He will thus form them into classes, and those that agree in less general characters into orders, and so on until those agreeing in still less important characteristics may be placed in categories or groups termed families, genera and species, varieties and races. For example, the cat belongs to the following groups:

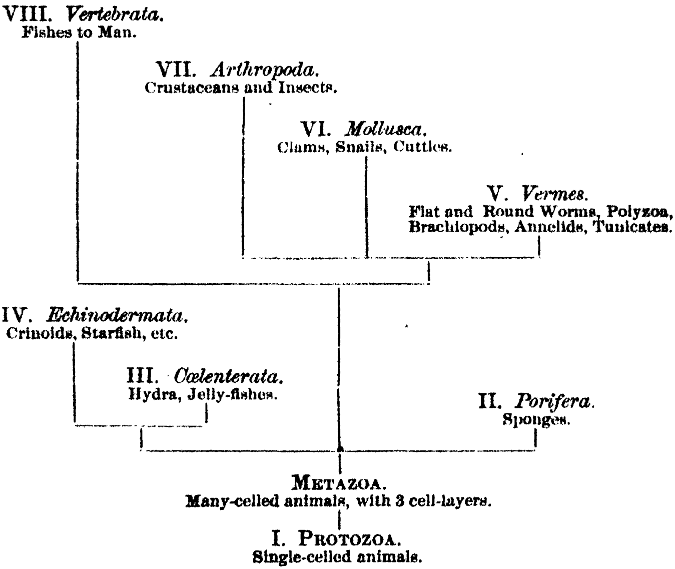
- *Kingdom* of Animals;
  - *Sub-kingdom*, or *branch*, Vertebrates;
    - *Class*, Mammalia;
      - *Order*, Carnivora;
        - *Family*, Felidæ;
          - *Genus*, Felis;
            - *Species*, *Felis domesticus* Linnæus;
              - *Variety*, *Angorensis*.

But these different groups are insufficient to represent the almost endless relationships and series called the *System of Nature*, which our classifications attempt to represent. Hence we have sub-species, sub-genera, sub-families and super-families, sub-orders and super-orders, and sub-classes and super-classes, and the different assemblages may be grouped into *series* of orders, families, etc.

The relations of the members of these different groups may be represented in the same manner as the genealogical tree of the historian, or like a tree, with its trunk and branches and twigs; or on a plane by a cross-section through the tree, the different groups or ends of the branches resembling a constellation, and embodying one's idea of the complicated relations between animals of different groups.

The Animal Kingdom may be divided primarily into two series of branches; those for the most part composed of a single cell, represented by a single branch, the *Protozoa*, and those whose bodies are composed of many cells (*Metazoa*), the cells arranged in three fundamental cell-layers—viz., the *ectoderm*, *mesoderm*, and *endoderm*. The series of *Metazoa* comprises the seven higher branches—*i.e.*, the *Porifera*, *Cœlenterata*, *Echinodermata*, *Vermes*, *Mollusca*, *Arthropoda*, and *Vertebrata*. Their approximate relationships may be provisionally expressed by the following

TABULAR VIEW OF THE EIGHT BRANCHES OF THE ANIMAL KINGDOM.



It should be understood by the student that the classification presented in this book is a provisional one, based on our present knowledge of the structure of the leading types of the animal kingdom, and may be regarded as rudely indicating the blood-relationship or pedigree of animals. It differs in some important respects from the classifications given in the books ordinarily in use by American students. It is a question whether the *Tunicata* should not form a ninth branch, and stand next below the Vertebrates.

Some authors retain the four types of Cuvier, but it should be remembered that since Cuvier's classification was proposed in 1812 our knowledge has been greatly extended. The microscope has revealed an immense mass of new microscopic forms, and many facts regarding the structure and development of the larger forms. The *embranchments* of Cuvier are in all cases, except the Vertebrates, unwieldy, heterogeneous, and, in the light of our present knowledge, unnatural assemblages of animals. New discoveries do away with old systems, and the classifications adopted by different authors represent the standpoint from which they regard the system of nature. It is not of so much consequence to the student to know what the system may be, as to learn the leading facts of animal morphology and development.

Palæontology.—With a thorough knowledge of the anatomy of animals and their classification, the student is prepared to study the remains of extinct animals, to restore so far as possible their forms, and to classify them. With a knowledge of the hard parts of existing animals, and of the interaction of the tendons, ligaments, muscles, and bones, the palæontologist can, in accordance with the law of correlation of parts, refer fossils to their respective orders, families, genera, or species.

Zoogeography, or geographical distribution, is the study of the laws of distribution of animals over the surface of the earth or over the bottom of the sea. The assemblage of animals inhabiting any area is called a *fauna.* Thus we have an arctic fauna, a tropical fauna, a North American fauna, or Australian fauna. The fauna of the ocean is subdivided into different subordinate faunæ.

CHAPTER I.

BRANCH I.—PROTOZOA.

General Characters of Protozoans.—We can imagine no more elementary forms of life than certain members of this branch, whose bodies in the simplest forms are merely masses of albumen, without any distinct permanent organs, or portions set apart for the performance of any special function. Yet the primary acts of animal life, such as taking food, its digestion and assimilation, and reproduction, are carried on as effectively by these lowest as by the highest forms. The simplest Protozoans are like minute drops of protoplasm or albumen, having a gliding motion, and constantly changing their forms, throwing out temporarily root-like projections called *pseudopodia*, which serve to gather food-particles. Fig. 7 illustrates a typical Protozoan. It is the common Amœba of standing water. Most Protozoans are provided with a central organ or nucleus, which corresponds to the reproductive organs of the many-celled animals. The Protozoa are one-celled in distinction from all other animals, from the sponges to man, which are many-celled, though it is claimed that a few shelled forms (Rhizopods) are composed of several indistinct cells. Thus a Protozoan corresponds to an egg or to any one of the cells composing the bodies of higher animals. They may be naked, as in *Protomœba* or *Amœba*, or may secrete a silicious or calcareous shell. The Infusoria, forming the highest class, are quite complicated, with permanent cilia, a mouth, throat, repro-

Fig. 7.—Amœba, the nucleus not shown.

ductive nucleus, and several contractile vesicles, rudely anticipating the heart of higher animals. Protozoans reproduce by self-division and the formation of motile germs (zoospores), and in the Infusoria of ciliated young. There is thus a great range of forms leading from the most primitive type (*Protamœba*) to the most specialized forms, such as the bell animalcule (*Vorticella.*)

CLASS I.—MONERA (*Moners*).

General Characters of Moners.—This group comprises the simplest forms of Protozoans, whence the name *Monera* (μονήρες, simple). The lowest forms are almost identical in appearance with the lowest plants, and they can only be claimed to be animals from their resemblance to higher forms leading to *Amœba*, which, in turn, is connected by a series of forms leading to undoubted animals, such as the shelled Rhizopods (Fig. 14).

8.—*Protomonas amyli*, greatly magnified. *A*, when encysted; *x*, germs or zoospores; *y*, food-mass. *B*, germ freed from the parent-cyst. *C*, *D*, older germs. *E*, adult encysted; *y*, food; *s*, projection inward of the cell-wall; *x*, wall of the cyst; *t*, germs.—After Cienkowski.

The *Monera* differ from the Rhizopods (*Amœba*, etc.) in wanting a nucleus and contractile vesicles. Their body-substance is homogeneous throughout, not divided into a tenacious outer and softer inner mass, as in *Amœba*. They move by the contraction of the body, and the irregular protrusion of portions of the body forming either simple processes (*pseudopodia*) or a network of gelatinous threads. The food, as some diatom, desmid, or protozoan, is swallowed whole, being surrounded and engulfed by the body, and the protoplasmic matter is then absorbed, serving for the nourishment and growth of the Moner.

The simplest form known, and supposed to be really a living being, is Haeckel's *Protamœba.* It may best be described by stating that it is like an *Amœba,* but without a nucleus and vacuoles (or little cavities). It reproduces by simple self-division, much as in *Amœba* (Fig. 11).

In *Protomonas* the body is very changeable in form, the pseudopods often being very slender, thread-like. Fig. 8, *A* represents this Moner during the formation of the young (zoospores) in the cyst-like body, or resting-stage of the creature; *B,* one of these germs freed from the cyst and capable of moving about by the two thread-like pseudopodia; *C D,* the Amœba-like form which the young afterward assumes, and which at maturity passes into the encysted or resting-stage *E.*

A still better idea of what a Moner is may be seen by studying the *Protomyxa aurantiaca* Haeckel.

This Moner was discovered at the Canary Islands. It is from half to one millimetre in diameter, and is a perfectly simple mass of orange-red jelly. When hungry numerous root-shaped threads (pseudopodia) radiate from the central mass. Fig. 9, *E* represents the *Protomyxa* after having absorbed into its body-mass a number of shelled *Infusoria.* When about to become encysted (*A B*) it rejects the shell of its victims, retracts its false feet, and soon becomes fastened as minute red balls to the surface of some dead shell.

The ball becomes enclosed by a thick covering (*A*), and then the contents become divided into several hundred small, round, thoroughly structureless spheres, which become germs (*B*). The germs finally burst through the cyst-wall, as in *C, a, c, d,* and assume various monad-like and amœboid shapes, and finally attain, by simple additions of the protoplasm of its food (diatoms and infusoria), the adult form (*D E*). Other Moners exist in fresh water.

We have been dealing with the simplest living forms, beings showing no trace of organization, much lower and simpler than the *Amœba,* with its nucleus. The individual

Moner—for example, *Protamœba*—is simply a speck or drop of transparent, often colorless, viscid fluid, scarcely of more consistency than, and in all apparent physical characters identical with, the white of a hen's egg. And yet this drop of protoplasm has the power of absorbing the protoplasm of other living beings, and thus of increasing in size—*i.e.*, growing; and in taking its food makes various movements, one or more parts of its body being more movable than others, the faculty of motion thus being for the moment specialized; it has apparently the power of selecting one kind of food in preference to another, and, finally, of reproducing its kind by a process not only of simple self-division, but also of germ-production. In short, we may say of the Moner what Foster says of the Amœba—viz., (1) it is *contractile;* (2) it is *irritable* and *automatic*; (3) it is *receptive*

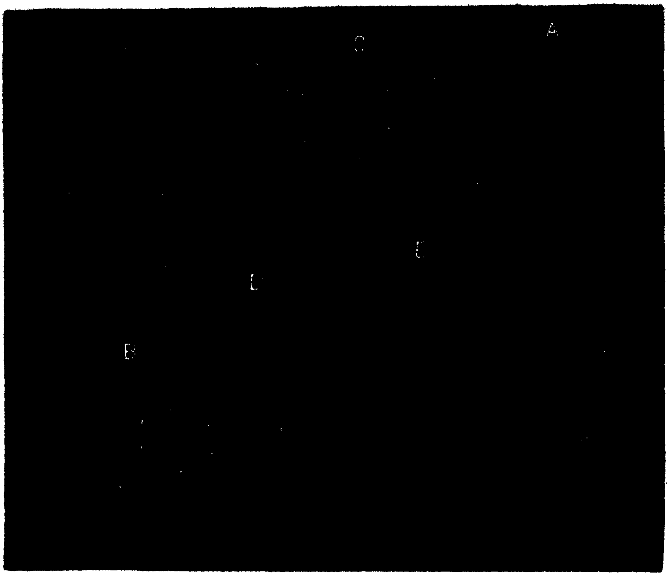


Fig. 9.—*Protomyxa aurantiaca.* *A*, encysted. *B*, cyst filled with germs. *C*, germs (*a*, *d*, *c*) issuing from the cyst. *D*, a young Protomyxa swallowing a diatom (*a*). *E*, adult after enclosing or swallowing several shelled Infusoria.—After Haeckel.

and *assimilative*; (4) it is *metabolic* and *secretory* in the sense that the Moner digests and separates the portions necessary for food from those which it rejects as waste; (5) it is *respiratory*, the changes involved in taking food, especially oxygen, causing the production of and excretion of carbonic acid; (6) it is reproductive.

It is difficult to conceive of a simpler form of life than *Protamœba* or *Protomonas*. Are the Moners animals or plants, or do they represent a neutral division or group of forms? It was formerly thought that *Amœba* was the simplest possible form of life, but we shall see that that animal is an undoubted *organism*, possessing a permanent *organ*, the *nucleus*. Moreover, the Amœba intergrades with the other Rhizopods which are undoubted animals, while the simplest Monera have no characters which absolutely separate them on the one hand from the plants or on the other from the animals. Their relation to the plants is seen in the fact that, besides the resemblance to the lowest plants, the cyst of *Protomonas* is composed of cellulose, while the granular contents of the body become colored with chlorophyll.*

For these reasons, Haeckel, the discoverer of the *Monera*, regards them as neutral beings, neither plants nor animals. But by comparison with other *Protozoa*, we shall see that the *Monera* only differ from the monads and *Amœbæ* by the absence of a nucleus. This may yet be found to occur in the Monera, and from this fact we separate the group only provisionally from the *Rhizopoda*. The *Gregarinæ* also pass through a true Moner-stage. This indicates that the *Monera* are allied rather to animals than plants. Another point of difference from plants is the fact that, like the *Amœba*, they engulf living plants (desmids, etc.) and animals (Infusoria), the only plants known to do this being the singular *Myxomycetes*, whose position is uncertain, some naturalists (Allman) regarding it as an animal.

It is probable that the *Monera* were the earliest beings to appear, and that from forms resembling them all other organisms have originated. We can conceive at least of no simpler ancestral form; and if organized beings were originally produced from the chemical elements which form protoplasm, one would be naturally led to suppose that the earliest form was like *Protamœba.* It would follow from this fact that the Monera are as low as any plants, and that animals appeared contemporaneously with plants.

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* On the other hand, cellulose occurs in the integument of Tunicates, and various parts of Articulates and Vertebrates, while chlorophyll occurs in the Infusoria and *Hydra*.

Having studied a few typical forms of *Monera,* we are prepared to briefly define the group and tabulate the subdivisions of the class.

CLASS I.—MONERA HAECKEL.

Beings consisting of transparent protoplasm, containing granules, sometimes forming a net-work, but with no nucleus or contractile vacuole; capable of automatically throwing out pseudopodia, and reproducing by simple self-division of the body-mass into two individuals, or by division into a number of germ-like or spore-like young, which increase in size by absorption of the protoplasm of other organisms.*

Group 1. *Gymnomonera,* comprising the genera Protamœba, Protogenes, and Myxodictyum, which do not become encysted.

Group 2. *Lepomonera,* which become encysted and protected by a case, as in the genera Protomonas, Protomyxa, Vampyrella, and Myxastrum.

CLASS II.—RHIZOPODA (*Root Animalcules*).

General Characters of Rhizopods.—An idea of the form and internal structure of this group can be obtained by a study of *Amœba,* which may be found sliding over the surface of the leaves of plants growing in pools or ponds of fresh water. Our common *Amœba* has been studied by H. J. Clark. Fig. 10 represents this animal in the three more usual forms which it assumes. From time to time the sides of its body project either in the form of simple bulgings, or suddenly it throws out foot-like projections

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* Should a nucleus be found hereafter to occur in the Monera, the group should be merged into the *Rhizopoda,* and placed next to *Amœba.*

(pseudopodia) from various parts of the body, as if it were falling apart; then it retracts these transparent feet and becomes perfectly smooth and rounded, resembling a drop of slimy, mucous matter. The body-mass is divided into a clear cortical and a medullary, granular mass; the outer highly contractile, the inner granular portion acting virtually as a stock of food. These granules, like the grains of chlorophyll in vegetable cells and in diatoms and desmids, circulate in regular, fixed currents, the arrows in the figure indicating the course of the circulating food. The act of circulation is probably assisted by a contractile vesicle (or vacuole) usually present. There is besides a distinct organ always present, the *nucleus* (see Fig. 11), so that the Amœba earns the right to be called an organism. Its food consists of one-celled algæ, diatoms, desmids, zoospores, and portions of filamentous algæ, and it possesses the power of discrimination in taking its food. The Amœba has the power of moving in particular directions, stretching a millimetre in length; it selects appropriate food, and can engulf or swallow, digest and distribute the food thus absorbed to various portions of

Fig. 10.—*Amœba diffluens* Ehr. *A*, the left-hand figure, the most usual form; the right shows the broad, flat pseudopodia; the arrows indicate the direction of circulation of the granules.—After Clark.

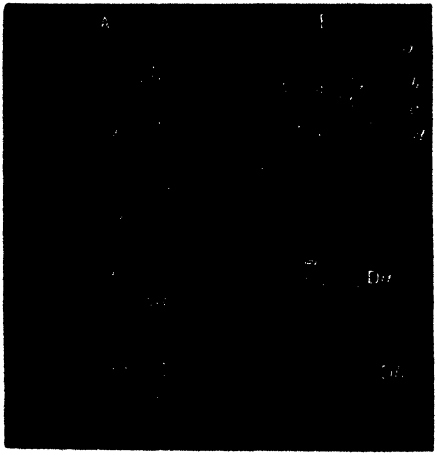

Fig. — ——— *sphærococcus*. *A*, before division. *B*, the same in its resting stage; *a*, cyst or cell-wall; *d*, body-mass; *c*, nucleus; *b*, nucleolus. *C*, Amœba nearly divided. *D*, two young Amœbæ, the result of division.—After Haeckel.

its body. The Amœba reproduces its kind by simple division, as seen in *Amœba sphærococcus* Haeckel (Fig. 11). This species, unlike others, so far as known, becomes encysted (*B*), then breaks the cell-wall and becomes free as at *A*. Self-division then begins as at *C*, the nucleus doubling itself, until at *D a* and *D b* we have as the result two individuals.

Order 1. *Foraminifera.*—Besides *Amœba*, several other forms, either naked or shelled, produce, by division of an inner portion of the body, numbers of ciliated young, as in the naked *Pelomyxa*, in certain many-chambered *Foraminifera*, and in *Collosphæra*. An example may be seen in the European *Pelomyxa palustris* Greef (Fig. 12). This creature lives in the mud at the bottom of fresh-water pools, and when first seen resembles little dark balls of mud a millimetre in diameter. Instead of one nucleus, there are numbers of them, and numerous contractile vacuoles filled with a fluid, together with spicules. The young are at first amœba-like (*B*), originating as "shining bodies," which have resulted from the self-division of the nuclei. These amœba-like bodies finally assume an active, monad-like stage *C*, and move about by means of a cilium or lash.

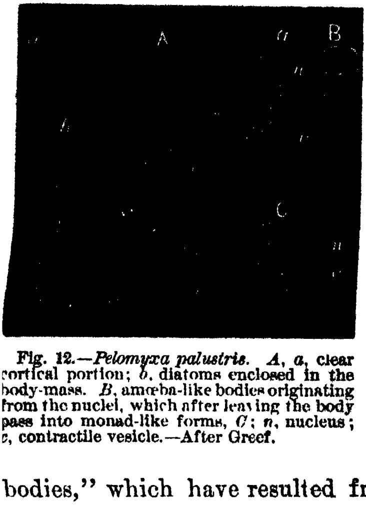

Fig. 12.—*Pelomyxa palustris*. *A*, *a*, clear cortical portion; *b*, diatoms enclosed in the body-mass. *B*, amœba-like bodies originating from the nuclei, which after leaving the body pass into monad-like forms, *C*; *n*, nucleus; *c*, contractile vesicle.—After Greef.

We now come to the shelled Amœbæ, or genuine *Foraminifera*. A common type is *Arcella*, which secretes a one-chambered silicious shell, found in fresh water, and a representative of the monothalamous, or one-chambered, *Foraminifera*; while the many-chambered forms are marine, of which *Globigerina bulloides* (Fig. 13), found floating on the surface of the ocean, with its pseudopodia thrown out in all directions, is a type; *Rotalia veneta* (Fig. 14) is another example.

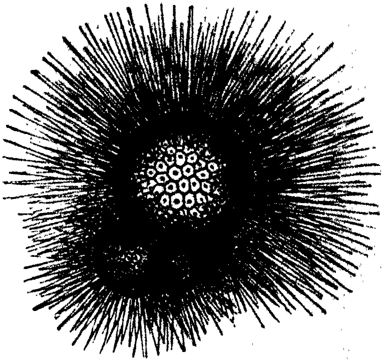

Fig. 13.—A Foraminifer. *Globigerina bulloides*, magnified 70 diameters.—From Macallister.

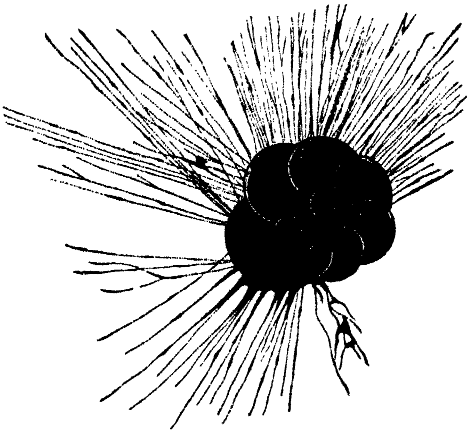

Fig. 14.—*Rotalia*. A Rhizopod, showing the pseudopodia.

The *Foraminifera* are nucleated. *Diplophrys* multiplies by a "process of continuous binary fission." ***Miliola*** gives rise to small round, sharply-defined bodies, in calcareous shells, with one turn, but no inner walls, and with pseudopodia like those of the adult. *Microgromia socialis* multiplies by zoospores, which are oval, with two flagella; or, in other cases, the young assume an actinophrys-like form, and move about by the aid of three or four more or less branched pointed pseudopods (Hertwig). In some forms, as the fossil chambers are numerous and regular, the shells being flat and consisting of eight coils situated in the same plane. A recent species of Foraminifer found at Borneo measures more than two inches in diameter, while a common form on the Florida reefs, devoured in large quantities by the *Holothuria*, or sea-cucumber, measures about one fifth of an inch in diameter. Most of our native species are much more minute. The Eozoon, so-called, is supposed by some to be a Foraminifer, but others regard it as more probably inorganic, and simply a mineral. Undoubted *Foraminifera* occur in the Silurian formation, while large masses of carboniferous and cretaceous rocks are formed by their shells.

Fig. 15.—*B*, *Collosphæra spinosa*, with projecting conical points, containing little spheroids, which pass into monad-like bodies *C*. *D*, probably an early stage of *C*. *A*, a young capsule of *C. Huxleyi* Müller.—After Cienkowski.

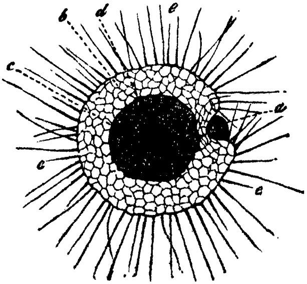

Fig. 16.—*Actinosphærium.* sel of food drawn into the cortical layer *b*; *c*, central parenchymatous mass of the body; *d*, some balls of food-stuff in the latter; *e*, pseudopodia of the cortical layer.—After Gegenbaur.

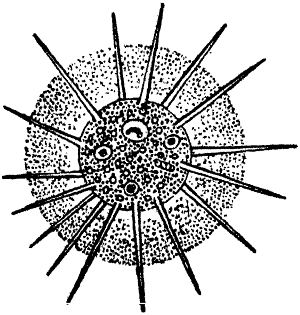

Fig. 17.—*Heliophrys variabilis.* A sun-animalcule, showing the pseudopods, nuclei, and vacuoles.—From Macallister.

Order 2. *Radiolaria.*—These Rhizopods have the general structure of Amœbæ, but secrete beautiful silicious shells, of varied forms, more or less spherical, perforated for the protrusion of the pseudopodia, with often spicules or points radiating from the shell. They reproduce apparently by self-division of the interior, resulting in a swarm of monad-like young. The *Heliozoa* are represented by the fresh-water *Actinophrys sol*, which is round, with numerous stiff pseudopodia radiating in all directions from the body, and by Actinosphærium (Fig. 16). The true marine *Radiolaria* are represented by *Collosphæra spinosa* Cienkowski (Fig. 15). It possesses a perforated shell beset with small spines, which encloses a capsule with a protoplasmic wall. In the capsule-stage (*A*) it often divides by fission into two halves. Afterward the older capsule divides into a number of little round bodies, which develop two lashes as in *C*.

CLASS II.—RHIZOPODA.

Unicellular organisms consisting of protoplasm, with an outer clear, cortical, and an inner granular mass containing one or more nuclei, and one or more contractile vacuoles; moving by means of pseudopodia, and either naked or secreting a one or many-chambered shell; reproducing by self-division, or by the production of several or many amœboid or monad-like young.

Order 1. *Foraminifera.*—One-celled Rhizopods with one or many nuclei and contractile vacuoles, secreting chambered calcareous or horny (chitinous ?), rarely arenaceous, shells. (Amœba, Globigerina, Nummulina.)

Order 2. *Radiolaria.*—Rhizopods with pointed, branched, usually anastomosing and granular pseudopodia. The body contains either numerous small heterogeneous nuclei, or a single larger, highly differentiated vesicular nucleus. The protoplasm of the body is further separated into a peripheral non-nucleated and a central nucleated portion by a membranous capsule with porous walls. Reproduction occurs by the breaking up of the body into monad-like embryos, with one or sometimes two locomotive lashes (flagella). There are two divisions: (1) *Heliozoa* (Actinophrys, Actinosphærium), and (2) *Radiolaria* (or *Cytophora*), having as representatives Acanthometra, Collozoüm, Sphærozoüm, and Collosphæra.

CLASS III.—GREGARINIDA (*Gregarines*).

General Characters of Gregarinida.—The largest and best known species of this group is an inmate of the intestinal canal of the European lobster, and was named by E. Van Beneden *Gregarina gigantea* (Fig. 18). It is worm-like, remarkably slender, and is sixteen millimetres (over half an inch) in length, being the largest one-celled animal known. In this organism an external, structureless, perfectly transparent membrane with a double contour can be distinguished. It represents the cell-wall of the cells in the higher animals. Beneath this outer wall is a continuous layer of contractile substance, forming a true system of muscular fibrillæ comparable to that of the Infusoria. The body-cavity of the Gregarina contains a

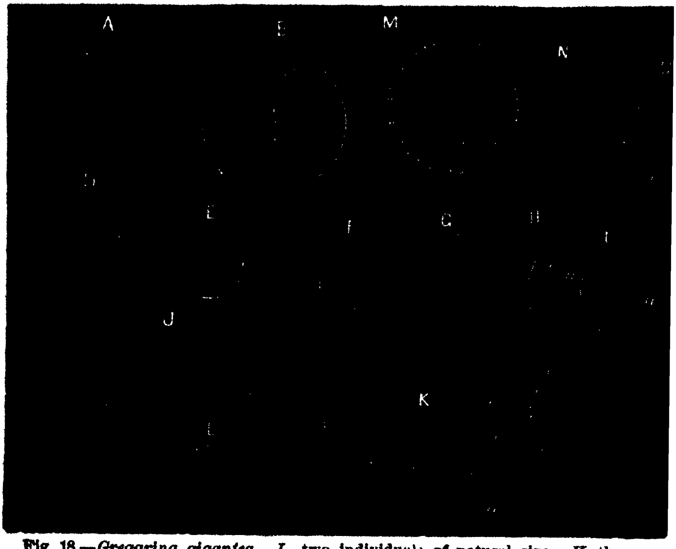

Fig 18.—*Gregarina gigantea* *L*, two individuals of natural size *K*, the same much enlarged, *n*, nucleus *A*, the same encysted *B*, subdivision of the cyst *C*, division of the contents of cyst into small spheres, observed in another species *N*, the spheres enlarged *M* cyst filled with pseudonavicellæ. *O*—After Lieberkuhn *D*—*F*, moner-like young of *G gigantea* *G*, *H*, pseudofilaria stage *I*, *J*, early nucleated forms of *Gregarina gigantea*—After Van Beneden

viscid fluid holding in suspension rounded granules, among which the nucleus rests. This nucleus contains an inner vesicle or nucleolus, which strangely disappears and then reappears. Van Beneden distinguishes three kinds of motions in the Gregarinæ: 1. They represent a very slow movement of translation, in a straight line, and without the possibility of distinguishing any contraction of the walls of the body which could be considered as the cause of the movement. It seems impossible to account for this kind of motion. 2. The next kind of movement consists in the lateral displacement of every part, taking place suddenly and often very violently, from a more or less considerable part of its body. Then the posterior part of the body may be often seen to throw itself out laterally by a brusque and instantaneous movement, forming an angle with the anterior part. 3. Owing to the contractions of the body, the granules within the body move about.

The life-history of this Gregarina is as follows: It occurs in its normal state in lobsters in May, June, and August, but in September becomes encysted in the walls of the rectum of its host, the cysts (Fig. 18, *A*) appearing like little white grains of the size of the head of a small pin. When thus encysted the nucleus disappears, and the granular contents of the cyst divide into two masses (*B*), like the beginning of the segmentation of the yolk of the higher animals. The next step is not figured by Van Beneden, and we therefore introduce some figures from Lieberkuhn which show how the granular mass breaks up into spindle-shaped bodies (called by some authors "pseudonavicellæ," and by Lieberkuhn "psorosperms") with hard shells. After the disappearance of the nucleus and vesicle, and when the encysted portion has become a homogeneous granular mass, this mass divides into a number of rounded balls (Fig. 18, *C*). These balls consist of fine granules, which are the spindle-shaped bodies in their first stage (Fig. 18, *N*). They then become spindle-shaped (*O*) and fill the cyst (Fig. 18, *M*), the balls having meanwhile disappeared. From these psorosperms are expelled amœba-like masses of albumen (*D E*), which, as Van Beneden remarks, exactly resemble the *Protamœba* already described. This moner-like being, without a nucleus, is the young Gregarina.

But soon the Amœbä characters arise. The moner-like young (Fig. 18, *D E F*) now undergoes a further change. Its outer portion becomes a thick layer of a brilliant, perfectly homogeneous protoplasm, entirely free from granules, which surrounds the central granular contents of the cytode (Haeckel) or non-nucleated cell. This is the Amœba stage of the young Gregarina, the body, as in the Amœba, consisting of a clear, cortical, and granular medullary or central portion.

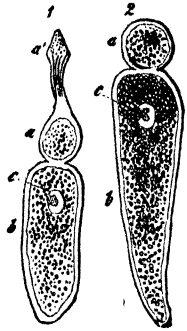

Fig. 19.—Gregarina from the alimentary canal of a beetle, *Opatrum sabulosum*. 1, younger state, with a beak-like continuation (*a'*) of the head. 2, older; *a*, anterior end; *b*, hinder part of the body; *c*, nucleus.—After Gegenbaur.

The next step is the appearance of two arm-like projections (Fig. 18, *F*), comparable to the pseudopods of an Amœba. One of these arms elongates, and, separating, forms a perfect Gregarina. Soon afterward the other arm elongates, absorbs the moner-like mass, and also becomes a perfect Gregarina. This elongated stage is called a *Pseudofilaria* (Fig. 18, *G*); no nucleus has yet appeared. In the next stage (Fig. 18, *H n*, nucleus) the body is shorter and broader, and the nucleus appears, while a number of granules collect at one end, indicating a head. After this the body shortens a little more (*I*, *J*), and then attains the elongated, worm-like form of the adult Gregarina (*K*). Van Beneden thus sums up the phases of growth:

1. The Moner phase.
2. The generating Cytode phase.
3. The Pseudofilaria phase.
4. The Protoplast (adult Gregarina).
5. The encysted Gregarina.
6. The sporogony phase (producing zoospores).

The Gregarinæ and Amœbæ constitute Haeckel's group of *Protoplasta*. Other Gregarinæ are very minute, and are parasitic in insects (Fig. 19), etc., and vary greatly in form, some being apparently segmented, while in a few forms the body ends anteriorly in a sort of beak armed with recurved horny spines. We are now prepared to adopt the following definition of the class:

CLASS III.—GREGARINIDA.

Amœba-like Protozoa, more or less elongated, with a determinate cell-wall, with a subcuticular system of muscular fibrillæ, with a nucleus, but no contractile vacuole; reproducing by encysting and subdivision of the central mass of the body, producing shelly psorosperms, from which escape the moner-like young, which undergo a metamorphosis into the usually worm-shaped, parasitic adult (Gregarina).

CLASS IV.—INFUSORIA.

These organisms can best be understood by studying representatives of the three orders forming the class.

Order 1. *Flagellata* (Monads).—A familiar example of monads, *Monas termo* Ehrenberg? has been studied by H. J. Clark. His description will suit our purpose of indicating the form and habits of a typical flagellate animalcule. It somewhat resembles our figure of *Uvella* in its general shape, being pear-shaped, faint olive in color, and provided with a vibratile locomotive lash or flagellum. In swimming, the monad stretches out the flagellum, which vibrates with an undulating, whirling motion, and produces a peculiar graceful rolling motion. When the monad is fixed the flagellum is used to convey food to the mouth, which lies between the base of the flagellum and beak, or "lip." The food is thrown by a sudden jerk, and with precision, directly against the mouth. "If acceptable for food, the flagellum presses its base down upon the morsel, and at the same time the lip is thrown back so as to disclose the mouth, and then bent over the particle as it sinks into the latter. When the lip has obtained a fair hold upon the food, the flagellum withdraws from its incumbent position and returns to its former rigid, watchful condition. The process of deglutition is then carried on by the help of the lip alone, which expands latterly until it completely overlies the particle. All this is done quite rapidly, in a few seconds, and then the food glides quickly into the depths of the body, and is enveloped in a digestive vacuole, whilst the lip assumes its usual conical shape and proportions." (Clark.)

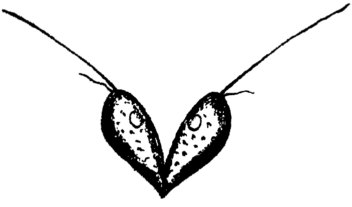
Fig. 20.—Monads (*Uvella*).—After Tuttle.

All the monads have a contractile vesicle. In *Monas termo*, Clark observes that it is "so large and conspicuous that its globular form may be readily seen, even through the greatest diameter of the body; and contracts so vigorously and abruptly, at the rate of six times a minute, that there seems to be a quite sensible shock over that side of the body in which it is embedded." The contractile vesicle is thought to represent the heart of the higher animals. The reproductive organ may possibly be represented in *Monas termo* by a "very conspicuous, bright, highly refracting, colorless oil-like globule which is enclosed in a clear vesicle" called the nucleus. This and other monads live either free or attached by a slender stalk. As an example of the compound or aggregated monads may be cited *Uvella*, probably *glauconia* of Ehrenberg. Other forms, as *Codosiga*, are fixed by a stalk to some object (Fig. 21, *C. pulcherrimus* Clark). In this and allied forms the body is surmounted by a collar or calyx out of which the flagellum projects. The Codosiga has been observed by Clark to undergo fission, two independent monads resulting, within the space of forty minutes.

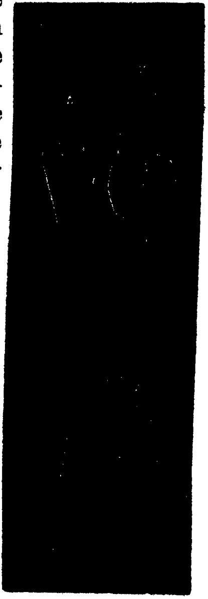
Fig. 21.—*A*, *Codosiga pulcherrimus*. *B*, the same beginning to undergo fission, two new flagella appearing. *C*, two nearly separate individuals.—After Clark.

The first sign of fission is a bulging out of the collar, which becomes still more bell-shaped. The flagellum next disappears. Then marks of self-division appear in a narrow, slight furrow (Fig. 21, *B*, *e*), extending from the front half way back along the middle of the body. Meanwhile the collar, which had become conical, expands, and, most striking change of all, two new flagella appear. Then the collar splits into two (Fig. 21, *C*), and soon the two new Codosigæ become perfected, when they split asunder, and become like the original Codosiga. Such is the usual mode of multiplication of the species in the monads.

A few monads have been observed to become encysted, and to break up into excessively minute bodies, from which new monads have grown. Two individuals of the same form (*Heteromita*) in certain stages fasten themselves together, the larger absorbing the smaller as if conjugating, like Desmids, the compound body resulting becoming encysted; finally the contents of the cyst become divided into either large or minute germs (*zoospores*) which assume the parent form. The researches of Messrs. Dallinger and Drysdale on this *Heteromita* have proved that while the mature forms may be destroyed at a temperature of 142° F., the motile germs of this and five other species of Infusoria perished when heated in fluid to from 212° F. to 268° F.

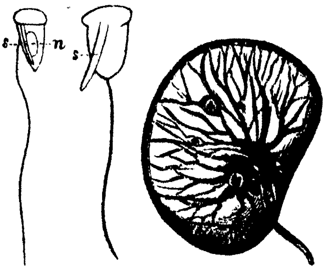

Fig. 22.—*Noctiluca miliaris*, after Huxley, and its zoospores. *s*, style; *n*. nucleus. Greatly magnified.—A [illegible]

Noctiluca (Fig. 22) has been proved by Cienkowski to be an enormous monad. It is a highly phosphorescent organism, so small as scarcely to be seen with the naked eye, being from ¼ to 1 mm. (·01 to ·04 inch) in diameter. It occurs in great numbers on the surface of the sea. It has a nearly spherical jelly-like body, with a groove on one side from which issues a curved filament, used in locomotion. Near the base of this filament is the mouth, having on one side a tooth-like projection. Connecting with the mouth is an œsophagus which passes into the digestive cavity, in front of which lies an oval nucleus. Beneath the outer skin or firm membrane surrounding the body is a gelatinous layer, containing numerous granules. A network of granular fibres arises from the granular layer; these fibres pass into the middle of the body to the nucleus and digestive cavity. The young (Fig. 22, *n*, *s*) result from a division or segmentation of the entire mass of the protoplasm of the body, forming small oval bodies with a long lash. The zoospores are like those of other *Flagellata*, and for this reason and the general structure of the adult, Noctiluca is by the best authorities associated with the Flagellata. Noctiluca also undergoes conjugation, but the zoospores appear whether conjugation has occurred or not. The Noctiluca on the coast of the United States has been observed in abundance on the surface of the sea in Portland harbor, by Mr. E. Bicknell. It is phosphorescent, but whether identical with *Noctiluca miliaris* of the European seas is not known. *Leptodiscus medusoides* Hertwig, is discoidal or medusiform in shape, the disk one and a half millimetres in diameter. When disturbed it darts through the water by the contractions of its umbrella-shaped body. It is allied to Noctiluca and was discovered at Messina.

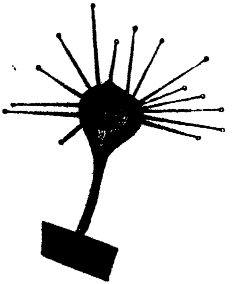

Fig. 23.—*Acineta mystacina*, with its stalk attached to a plant; with fifteen tentacles ending in knob-like expansions or suckers.—From Macallister.

Peridinium is the type of a third and higher division of monads, the body being protected by a hard shell, with one or more flagella, and a row of cilia serving as a locomotive apparatus, and thus, together with *Heteromastix* and *Dysteria*, connecting the *Flagellata* with the *Ciliata* or true *Infusoria*.

Order 2. *Tentaculifera* (Acinetæ, Suctoria).—An *Acineta* (Fig. 23) reminds us at first sight of a Radiolarian, since the body is provided with filiform, tentacle-like processes resembling the pseudopodia of a Radiolarian, but the tentacles are in reality rather stiff, hollow, and act as suckers, so that when the organism has by means of its hollow arms or tentacles caught some Infusorian, the arms contract, draw the victim nearer to the *Acineta*, and when the sucking disk at the end of the arms has penetrated the skin, the contents of the body of the Infusorian are sucked into the food-cavity of the *Acineta;* on the other hand, in some Acinetæ a portion of the arms are simply prehensile. These animals are in their adult phase quite unlike the *Flagellata* or *Ciliata*, but the young are developed within the parent and are provided with cilia, being at first free-swimming, and afterward fixed by a long stalk. The *Acinetæ* sometimes self-divide, sending off from the free end of the body a ciliated Acinete; they have also been seen to conjugate.

Order 3. *Ciliata* (Infusoria).—A common type of this group and one easy to obtain by the student is *Paramecium* (Fig. 24), observed in infusions, or moving rapidly over the bodies of larger animals which may be under the microscope. Figure 24 represents *Paramecium caudatum* Ehrenberg. This animalcule is a mass of protoplasm, representing a single cell. In the body-mass are ex-

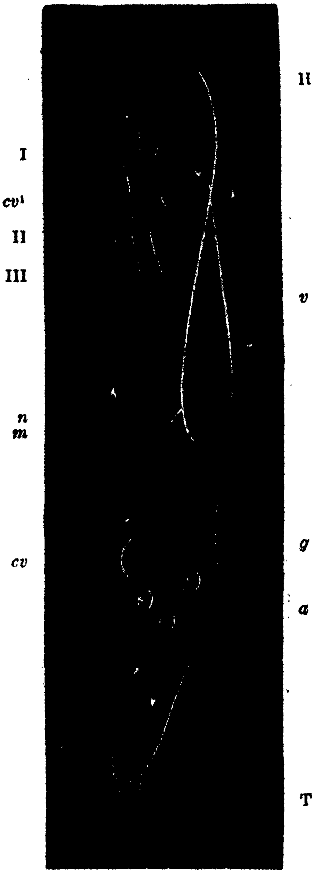

Fig. 24.—*Paramecium caudatum*. A view from the dorsal side, magnified 340 diameters. *H*, the head; *T*, the tail; *m*, the mouth; *m* to *g*, the throat; *a*, the pos- [illegible] vesicles; I, II, III, the radiating canals of *cv*¹; *n*, the reproductive organ; *v*, the large vibrating cilia at the edge of the vestibule.—After H. J. Clark.

cavated a mouth and a throat leading to a so-called stomach or digestive cavity. Two hollows in the body form the contractile vesicles, and another cavity constitutes the reproductive organ. Prolongations of the body-mass form the cilia, which characterize the Infusoria and give the name to the present order, *Ciliata.* *Paramecium* has an elongated, oval body "with one end (*H*) flattened out broader than the other, and twisted about one third way round, so that the flattened part resembles a very long figure 8." In this form, as well as in *Stentor* (Fig. 25), as Clark remarks, "we have the mouth at the bottom of a broad notch or incurvation, and the contractile vesicle on the opposite side, next the convex back, whilst the general cavity of the body lies between these two." The arrows in the figure represent the course of the particles of indigo with which Clark fed his specimens, "as they are whirled along, by the large vibrating cilia (*v*) of the edge of the disk, against the vestibule of the mouth." During the circuit the food is digested, a mass of *rejectamenta* is formed near the protuberance, *a,* which has appeared a short time before. This finally

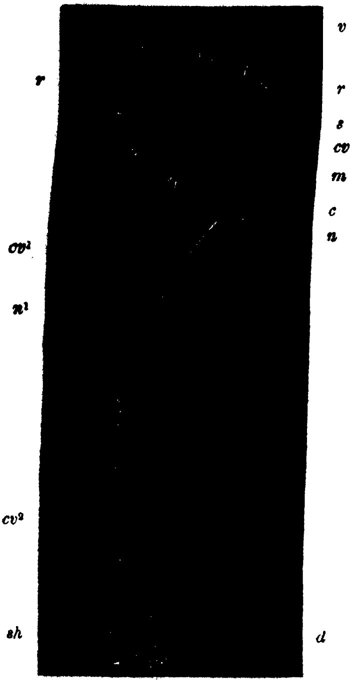

Fig. 25.—*Stentor polymorphus,* magnified 130 diameters, expanded and bent slightly over toward the observer; the mouth *m,* next the eye, and the dorsal edge in the distance. *a,* posterior end; *sh,* the tube enclosing *a*; *c,* the ciliated border of the disk (*s*); *v,* the larger rigid cilia; *cv,* the contractile vesicle in the extreme distance, seen through the whole thickness of the body; *cv*^{1}, *cv*^{2}, the posterior prolongation of *cv,* in the distance; *r*, *r*^{1}, the circular and radiating branches of what, by Clark, was supposed to be a rudimentary nervous system; *n*, *n*^{1}, the reproductive system, extending from the right side, at *n,* posteriorly, but toward the eye at *n*^{1}. —After Clark.

opens, allows the rejected matter to pass out, and then closes over, leaving no trace of an outlet. This and other Infusoria seem, then, to have a definite digestive tract, hollowed out of the parenchyma of the body.

"The system," says Clark, "which is analogous to the blood-circulation of the higher animals, is represented in Paramecium by two contractile vesicles (*cv*, cv^1, I, II, III), both of which have a degree of complication which, perhaps, exceeds that of any other similar organ" in these animals. When fully expanded they appear round, as at *c v*; but when contracted they appear, observes Clark, as "fine radiating streaks, and as the main portion lessens they gradually broaden and swell until the former is emptied and nearly invisible, and they are extended over half the length of the body. In this condition they might be compared to the arterial vessels of the more elevated classes of animals, but they would at the same time represent the veins, since they serve at the next moment to return the fluid to the main reservoir again, which is effected in this very remarkable way." The contents of these vesicles is a clear fluid.

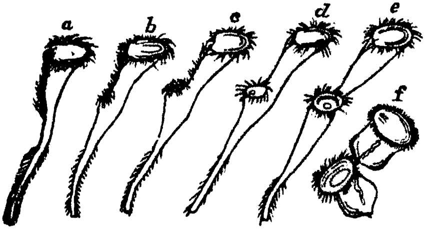

Fig. 26.—Process of fission in *Stentor polymorphus*. *b*, a new Stentor budding out; *e*, ready to separate from the original one; *f*, the two in a contracted state.—After Cox.

The reproductive organ in Paramecium is a small tube (*n*), only seen at the reproductive period when the eggs (*n*) are fully grown. Clark says that the eggs are arranged in it "in a single line, one after the other, at varying distances." It usually lies in the midst of the body, and extends from one half to two thirds of the length of the animal. The eggs pass out from the so-called ovary through an aperture near the mouth. Lasso-cells like those in the jelly-fishes are said by Bütschli to exist in an infusorian named by him *Polykrikos*.

In the trumpet animalcule (Fig. 25, *Stentor polymor-*

phus Ehrenberg) we have a rather more complicated form, the infusorian attaching itself at one end by a stalk, and building up a slight tube, into which it contracts when disturbed. The Stentor may be sometimes observed multiplying by self-division. Clark observed *Stentor polymorphus* undergoing the process. The first change observed was the division of the contractile vesicle into two. The mouth of the new Stentor was formed in the middle of the under side,

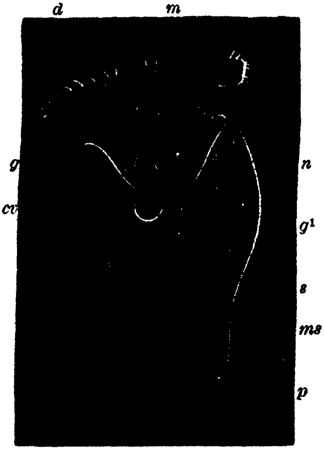

Fig. 27.—*Epistylis flavicans* Ehr., a single, many-forked colony of bell animalcules, slightly magnified. Fig. 28, one of the animalcules magnified 250 diameters. *p*, the stem; *d*, the flat spiral of vibrating cilia at the edge of the disk; *ms*, the muscle; *m* to *s*, the depth of the digestive cavity; *m*, the mouth; *g*, g^1, the throat, or rudimentary digestive canal; *cv*, the contractile vesicle; *n*, the reproductive organ or nucleus.—After Clark.

first appearing as a shallow pit, around which arises a semicircle of vibratile cilia. The mouth and throat form in the new Stentor before any signs of division appear, but in the course of two hours the body splits asunder, and two new individuals appear. Fig. 26 illustrates the mode of self-division seen in *Stentor polymorphus* Ehrenberg, by Hon. J. D. Cox. The process in this occupied two hours; at the final stage (Fig. 26, *f*) the connection between the two animalcules parted, "and the two Stentors swam separately away, both assuming the common form of the animalcule when free-swimming, and differing from the original individual only in being of smaller size."

The most complicated as well as most interesting form of all the Infusoria is the bell-animalcule, *Vorticella*. It is very common in pools, forming patches like white mould on the leaves and stems of submerged plants. It may, like Stentor, be observed under low powers of the microscope. Their motions, as they suddenly contract and then shoot out their bell, mounted on a long stalk, are very interesting. The throat (œsophagus) is quite distinct, while the nucleus is the most conspicuous organ of the body. The digestive cavity is a large hollow in the protoplasm forming the body-mass, in which the whole mass of food revolves in a determinate channel. Closely allied to *Vorticella* is *Epistylis* (Figs. 27 and 28).

While most ciliate Infusoria, so far as known, multiply by self-division, in *Vaginicola* the process is more like true gemmation or budding, and is accompanied by a process of encysting, resulting in the production of a free-swimming ciliated embryo, the adult *Vaginicola* being attached. The *Vorticella* also becomes encysted, and the nucleus subdivides until the body becomes filled with monad-like germs, the result of the simultaneous breaking up of the nucleus. The *Vorticellæ*, then, pass through a flagellate or monad stage, from which they pass into the *Vorticella* condition, when they multiply by self-division and by budding, the last generation becoming encysted.

Conjugation is a common occurrence in ciliate Infusoria, and results in the breaking up of the nucleus of each individual into a number of fragments, and the appearance in each of the individuals of the nucleus and nucleolus (either single or multiple) which characterize the species.*

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* Balbiani believes that the ciliate Infusoria have eggs which are fertilized by spermatic particles. More recently, however, Engelmann, Bütschli, and Hertwig have denied that conjugation is of a truly sexual character, and that the striated nucleoli of certain individual Infusoria are spermatozoa. "Nevertheless," remarks Huxley (Anatomy of In-

CLASS IV.—INFUSORIA.

Flagellate or ciliate (sometimes only ciliate in the early stages) Protozoa, the body not changing in form, having a definite skin, and often wholly or partly provided with cilia; usually free, sometimes stalked or attached; with a mouth-opening and œsophagus, and rudiments of digestive, circulatory (two or more contractile vesicles), and reproductive organs (nucleus and nucleolus), but with no distinctively sexual organs.

Order 1. *Flagellata.*—Rounded, oval, or pear-shaped organisms, usually exceedingly minute, provided with one or two flagella, with an oral region, into which particles of food are thrown by the flagellum; with a nucleus and contractile vesicles, rarely stalked, and with a calyx; sometimes aggregated; with a row of cilia in the highest forms serving as a locomotive apparatus; reproducing by self-division or by segmentation of the protoplasmic contents of the body, the young being minute oval bodies, provided with a flagellum (Monas, Heteromita, Noctiluca, Peridinium).

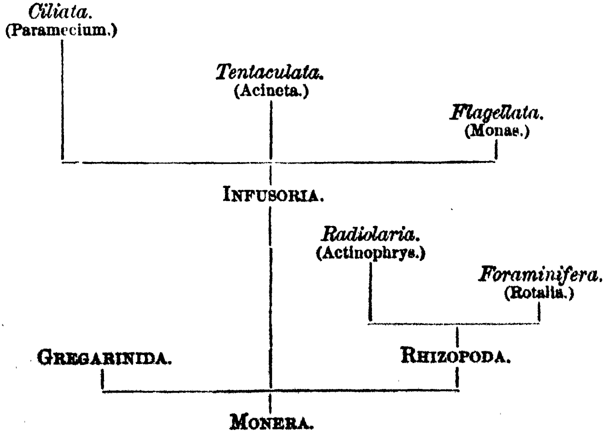
Order 2. *Tentaculifera* (Suctoria). — Naked, not ciliated, protozoans, with long, stiff, retractile arms or tentacles, provided with a sucker at the end, the arms hollow, conveying the food to the digestive cavity; originating from ciliated young; also by self-division throwing off ciliated forms, and undergoing conjugation (Acineta).

Order 3. *Ciliata* (True Infusoria).—Body free and covered with cilia (*Paramecium*, *Stentor*, etc.), or stalked, with the cilia confined to the head end (*Vaginicola* and *Vorticella*, etc.); a well-defined mouth and œsophagus; a digestive cavity and vent; a large nucleus, and two or more contractile vesicles. Reproducing by self-division, budding or conjugating, and producing monad-like young by self-division of the nucleus; sexuality doubtfully indicated.

The following diagram represents the relative position of the orders and classes of *Protozoa*, and in a rude way their possible genetic relations:

vertebrated Animals, p. 662), "it is still possible that the conjugation of the Infusoria may be a true sexual process, and that a portion of the divided endoplastules [striated nucleoli] of each may play the part of the spermatic corpuscle, the conjugation of which with the nucleus of the ovum appears, from recent researches, to constitute the essence of the act of impregnation."

VIEW OF THE CLASSIFICATION OF THE PROTOZOA.



Laboratory Work.—None of the *Protozoa*, except the shells of the *Foraminifera* and *Radiolaria*, can be well preserved after death, and it is always better to study any animal alive or freshly killed than when preserved in any sort of fluid. Fresh-water *Amœbæ* and *Monera* should be looked for on the surface of leaves and the stems of submerged plants in ponds, pools, and ditches. Many fresh-water Rhizopods dwell in sphagnum swamps and in damp moss or in shaded pools. The marine forms may be gathered with a fine towing net, when the surface of the ocean is calm. The commoner *Foraminifera* will be found on shells and stones at low-water mark or in shallow water, but most abundantly at greater depths—*i. e.*, from ten to one hundred fathoms. On being placed in water they will, after a period of rest, send out their pseudopodia.

To study their form and development they should be placed in a drop of water in an animalcule or aquatic box, and kept in this way for several days and even weeks, the box being examined daily, and water added if necessary. The shells may be studied by grinding and slicing into transverse and longitudinal sections. The animals of *Miliola* and other forms (*Rotalia*, *Textillaria*), on being treated with diluted chromic acid and stained with carmine, disclosed to Hertwig a well-marked nucleus. The nucleus may also be deeply stained by hæmatoxylin or carmine, and may be clearly demonstrated by acetic acid, which tends to destroy the surrounding protoplasm. Much ingenuity, mechanical skill, and patience is required in the study of the Protozoa, and much yet is to be learned regarding their mode of development and their structure.

CHAPTER II.

BRANCH II.—PORIFERA (SPONGES).

General Characters of Sponges.—Although the sponges were formerly supposed to be compound or social Amœbæ, and more recently monads, from the striking resemblance of their epithelial cells to certain monads, and have been generally regarded as Protozoans, later researches have shown that they are in reality many-celled animals, and that for a short period of their life they follow the same developmental path as the higher animals. It was also discovered that they reproduce by eggs, the latter undergoing segmentation and assuming the condition of a three-layered sac, the three layers being identical with those of the higher branches of the animal kingdom, so that the gap between the Protozoans and sponges is a wide one, and the latter are more nearly allied to the *Hydra*, for example, than to any one-celled animal.

One of the simplest sponges, such as *Ascetta primordialis* Haeckel, is a spindle or vase-shaped cylinder, attached by its base, with the cellular soft portion supported by a basket-work of interlaced needles or spicules of silex or lime. The cells are arranged in three layers, the innermost (endoderm) being provided each with a cilium. The spicules, and also the eggs, are developed in the middle layer (mesoderm). Moreover, the walls of the body are perforated by multitudes of small pores (whence the name of the branch, *Porifera*), through which the water percolates into the body-cavity, carrying minute forms of life or food-particles, which are individually thrown into each cell by the action of the single cilium thrust out of the collar of the cell, much as in an individual monad such as *Codosiga* (Fig. 21). Each cell rejects its own waste particle of food, the protoplasm having been previously absorbed, and the waste from all the epithelial cells is collectively expelled from the single excurrent orifice (*osculum*), there being many pores or mouths, and but a single outlet for the rejectamenta.

Such is the structure of one of the simplest sponges ; the larger common sponges differ mainly in having a less definite form, with numerous sacs or digestive cavities or chambers, and numerous excurrent orifices or *oscula*. It will be seen, then, that we have in the sponge a three-layered sac, its cavity rudely foreshadowing the gastrovascular cavity of the *Hydra*, but with no genuine mouth, the pores or so-called mouths simply allowing the sea-water laden with sponge-food to flow in, inflowing currents being formed by the ciliary action of the digestive cells, and the excurrent orifice permitting its exit.

In the other sponges such as are figured in this chapter, the structure is a little more complicated than in the *Ascetta*. There is no general body-cavity, with a continuous lining of epithelial cells, but the entire sponge-mass is permeated by large canals ending in oscula, and there are innumerable pores (so-called mouths) leading by branching canals to little pockets or cavities, which are lined with the flagellate, collared cells developed specially from the inner cell-layer (endoderm) ; so that the animal is myriad-stomached, so to speak. Moreover, the middle layer of cells is in many sponges greatly thickened, and nearly the whole mass, as seen in the common sponge, consists of spicules or horny fibres, and protoplasm, through which the excurrent and incurrent channels meander. Thread cells or lasso-cells like those hereafter to be described in Hydra have been detected in the sponge named *Reniera*.

Let us now follow out the life-history of a sponge. The sponges are further distinguished from the Protozoa in producing eggs and spermatic particles, the eggs being fertilized before leaving the sponge. The egg after fertilization divides in two, four, eight, sixteen, and more spheres, attaining the mulberry or *morula* * state (Fig. 29). The result is

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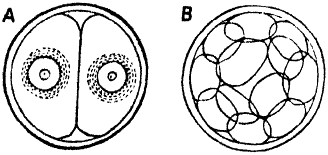
* The terms *morula* and *gastrula* are used in this book simply for

the formation of a two and afterward three-layered sac, corresponding to the *gastrula* of the higher animals. In this state (Fig. 30) the germ breaks out of the parent sponge into the sea. Fig. 31 represents the development of the common little calcareous sponge (*Sycon ciliatum*), found between tide-marks. *A* indicates the morula with the segmentation-cavity (*c*), which afterward disappears as at *B*. The gastrula is represented at *C*, and consists of ciliated and non-ciliated large round cells; the first series forming a sort of arch, with a hollow in the middle, around which a large number of very fine brown pigment corpuscles are collected. The next change of importance is the disappearance of the cavity, the upper or ciliated half of the body being much reduced in size. Then the large round cells of the hinder part are united into a compact mass, leaving only a single row. The ciliated cells are gradually withdrawn into the body-cavity. Fig. 31, *D*, shows this process going on. At this period also the larva becomes sessile, and now begins the formation of the sponge-spicules, which develop from the non-ciliated round cells. Metschnikoff calls attention to the fact that at this early stage the *Sycon* passes through a phase which is persistent in the genus *Sycyssa*. The layer of ciliated cells are gradually withdrawn into the body-cavity, until a small opening is left surrounded with a circle of cilia. These cilia finally disappear, a few more spicules grow out, and meanwhile the opening disappears. In the next stage (represented at *D*) a considerable body-cavity ap-



29.—Segmentation of egg of sponge *arca*).—After Carter.

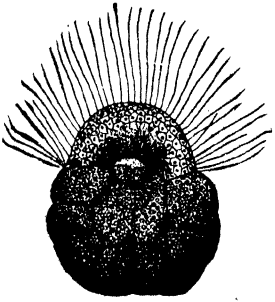


Fig. 30.—Gastrula of a sponge (*Sycandra raphanus*).—After Schulze.

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convenience to avoid circumlocution. It may be that these conditions will be found to be essentially modified in different groups of animals.

pears which may be seen through the body-walls. At this time the germ consists of two layers, the inner layer of ciliated cells (endoderm) forming a closed sac, enveloped in the spiculiferous layer. Such are the observations of Metschnikoff on the development of *Sycon.* According to the observations of Barrois, the larva or gastrula fixes itself by what are destined to be the ectodermal cells, and which are the round non-ciliated cells forming the posterior end (Fig. 31, *C*) of the free-swimming gastrula. About this time the mesoderm separates from the endoderm, either before or just after the gastrula becomes stationary, according to the group to which it belongs.

When the young sponge becomes stationary it does not differ from the gastrula, except that it becomes more or less irregular in form. Then appear the food or digestive cavities in the endoderm, in *Sycandra* becoming radiating tubes lined with ciliated, collared, monad-like cells ; or in *Leucon* and *Halichondria*, and their allies, forming scattered pockets, called "*ampullaceous sacs.*" In most sponges (except some calcareous species) there is no general body-cavity in the gastrula, nor in the young after the larva becomes stationary, according to Barrois. After the formation of the ampullaceous sacs the pores open through the mesoderm and connect the sacs and ciliated channels, as the case may

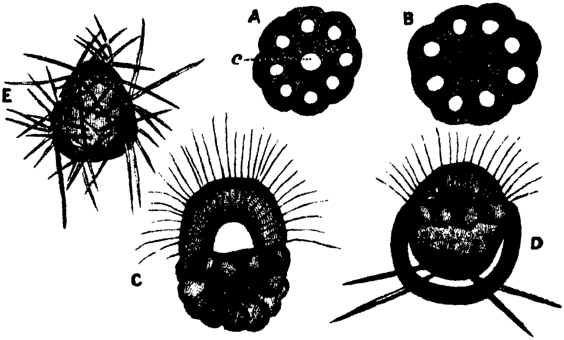


Fig. 31.—Development of a sponge (*Sycon ciliatum*).—After Metschnikoff.

be, with the outer world. These pores may open and then be permanently closed, new ones opening elsewhere. The osculum bursts open by the accumulation of water between the two layers in the same manner as the pores. Finally, in certain sponges the horny fibres grow out from the outer cell-layer and extend inward, surrounding the spicules, the latter developing from the middle cell-layer.

It appears, also, that all sponge embryos form a two and afterward three-layered sac (gastrula), in which in the simplest sponges there is a primitive body-cavity and a primitive mouth, while in the higher calcareous sponges and in the silicious forms the body-cavity is only temporarily open, being afterward filled up by the interior ciliated cells, and thus forming a compact mass.

In the sponges, also, the larva or free-swimming young is a three-layered sac, which is either hollow or, more commonly, solid, and may attach itself at the end of its free-swimming life by one end to some fixed object. The body-cavity may persist in the simpler forms through life, though in most sponges there is no genuine digestive cavity, but a large series of minute digestive sacs communicating by canals with the large ones leading to the oscula. The more or less regular spherical form of the young of most sponges becomes lost as they grow ; they become irregular in form, encrusting rocks, and their development retrogrades rather than advances.

In the fresh-water *Spongilla* there is a special provision for the maintenance of the species. In autumn are formed the so-called " seed," being capsules in which are enclosed eggs which in the spring develop young sponges. This cyst or capsule may be compared to the buds or winter eggs of the *Polyzoa* or of the water-flea (*Daphnia*).

From the members of the next branch, the sponges differ in the great irregularity of their form, the lack of a definite digestive cavity and of tentacles.

Order 1. *Calcispongiæ.*—The sponges may conveniently be divided into two orders. Those belonging to the first secrete spicules of lime, and there are no digestive or ampullaceous sacs, but the minute canals are lined with ciliated cells.

The calcareous sponges are few in number and are represented by a delicate little white sponge called *Sycon ciliatum* Johnston, very common on sea-weeds between tide-marks.

Order 2. *Carneospongiæ.*—In this group the spicules may either be fibrous and horny or silicious. The middle cell-layer is very thick, the endoderm being restricted to the numerous digestive cavities or so-called ampullaceous sacs.

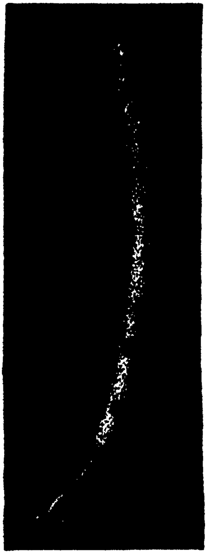


Fig. 32.—*Axinella polypoides.*

Fig. 33.—*Hyalonema boreale,* natural size.—After Lovén.

The fresh-water sponge (*Spongilla*) occurs everywhere on submerged sticks and stones in running or nearly stagnant water, usually branching. With the exception of *Spongilla* and another form, *Siphydora echinoides* Clark, which grows as large as one's fist in northern ponds and streams, all sponges are marine. One of the commonest sponges north of New York is *Chalinula oculata* (Bowerbank), which grows in long slender branches on the piles of wharves and bridges. Allied to it is Axinella (Fig. 32, *A. polypoides*).

Allied to *Tethea*, which is sessile, is a deep-sea form growing on a long stalk, *i.e.*, *Stylocordyla boreale* (Fig. 33). At the depth of 100 fathoms in the Gulf of Maine occurs a similar species (*S. longissimum* Sars). Fig. 34 represents a fine silicious sponge (*Pheronema Annæ* Leidy) from the West Indies. The most beautiful of all silicious sponges is the Venus' flower-basket (*Euplectellum aspergillum*), which lives anchored in the mud at the depth of about 10 fathoms, near the Philippine Islands.

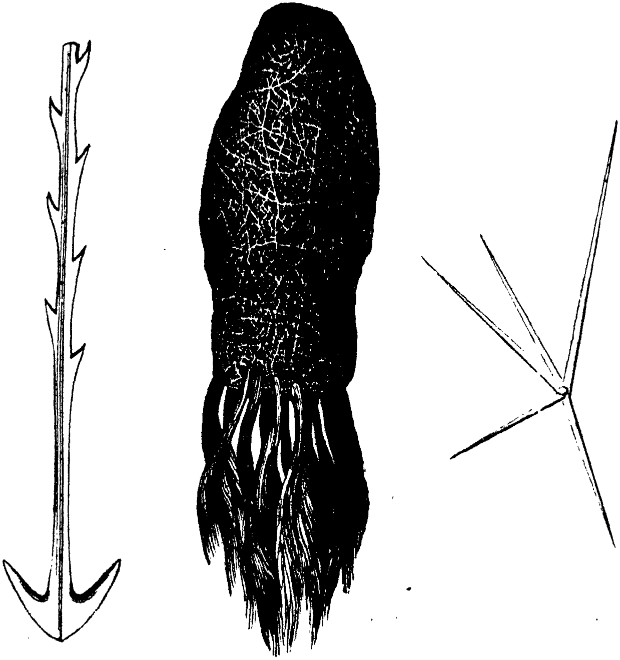


Fig. 34.—*Pheronema Annæ*, half natural size, with stellate and anchor-like spicules, much enlarged.—After Leidy.

The *Cliona* bores into shells, causing them to disintegrate. For example, *Cliona sulphurea* of Verrill has been found by him boring into various shells, such as the oyster, mussel, and scallop ; it also spreads out on all sides, enveloping and dissolving the entire shell. It has even been found to penetrate one or two inches into hard statuary marble.

Of the marketable sponges there are six species, with numerous varieties. They are available for our use from being simply fibrous, having no silicious spicules. The Mediterranean sponges are the best, being the softest; those of the Red Sea are next in quality, while our West Indian species are coarser and less durable. Our glove-sponge (*Spongia tubulifera* Duch. and Mich.) corresponds to *Spongia Adriatica* Schmidt, which is the Turkey cup-sponge and Levant toilet sponge of the Mediterranean. *Spongia gossypina* Duch. and Mich. the wool sponge of Florida and the Bahamas, corresponds to *S. equina* Schmidt, the horse or bath sponge of the Mediterranean.

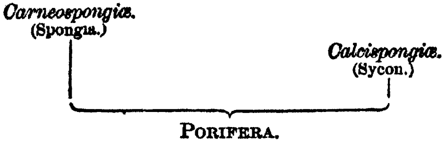
BRANCH II.—PORIFERA.

The sponges are many-celled animals, with three cell-layers, without a true digestive cavity, supported usually by calcareous or silicious spicules, the body-mass permeated by ciliated passages, or containing minute chambers lined by ciliated, collared, monad-like cells. No true mouth-opening, but usually an irregular system of inhalent pores opening into the cell-lined chambers or passages through which the food is introduced in currents of sea-water, the waste particles passing out of the body by a single, but more usually, many cloacal openings (oscula). Sponges are hermaphroditic, multiplying by fertilized eggs, the germ passing through a morula and a gastrula stage. (The characters of the Class the same as those of the Branch.)

Order 1. *Calcispongiæ.* Animal supported by a framework of calcareous spicules, disposed in lines or columns at right angles to the walls ; with cell-lined radiating canals. (Sycon.)

Order 2. *Carneospongiæ.* Mesoderm exceedingly thick ; the ciliated cells restricted to cell-lined chambers. Either no solid framework, as in Halisarca, or usually a well-developed fibrous or silicious framework. (Spongilla, Spongia, Hyalonema, Euplectella.)

VIEW OF THE CLASSIFICATION OF THE PORIFERA.



Laboratory Work.—Sponges are difficult to preserve alive in aquaria for study. Fine microscopic sections of the living sponge may be made with the razor or the microtome, and the tissues and eggs as well as the young be studied, though, from their minuteness, the study of the young is very difficult. The ciliated young of *Sycon ciliatum* may be obtained in the spring and summer by picking a portion of the sponge to pieces and tearing out small fragments with fine needles, until portions are small enough to be examined under high powers of the microscope. Researches on the finer structure and mode of growth of the sponge are difficult, and require much skill and long training in histological methods The gross structure of sponges may be studied by cross and longitudinal sections made with a razor or knife.

CHAPTER III.

BRANCH III.—CŒLENTERATA (HYDROIDS, JELLY-FISHES AND POLYPS).

General Characters of Cœlenterates.—In this branch, which is represented by animals like the *Hydra* (Fig. 36) and *Tubularia* (Fig. 35), the body consists of three cell-layers, surrounding a definite, single, digestive cavity, the mouth of the cavity being surrounded by a circle of tentacles, which are hollow and connect directly with the stomach. The latter, however, is only partly differentiated or set apart from the body, hence the name *Cœlenterata* (Greek, κοιλος, hidden, and ἐντερον, digestive tract). From the stomach often radiate water-vascular canals, no blood-system yet appearing thus far in the animal kingdom, the products of digestion reaching the tissues from the smaller branches of the primary water-vascular canals. The nervous system is either absent, or in different grades of development, from the isolated nervo-muscular cells of Hydra and the scattered nerve-cells of an *Actinia*, to the continuous ganglionated nervous ring of the minute jelly-fish such as *Sarsia*. These animals display a striking amount of radial symmetry, the organs and body being disposed in a radiate manner around a central vertical axis, in

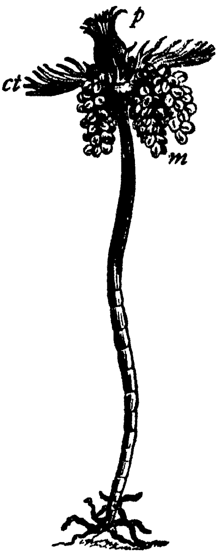


Fig. 35.—A Hydroid, *Tubularia*. *m*, medusa buds; *ct*, tentacles; *p*, proboscis.—From Tenney's Zoology.

part formed by the digestive tract. The Cœlenterata present striking examples of self-division, gemmation, and alternate generations, and very great extremes in degree of complexity of structure.

The different groups have a high geological antiquity; the species of Hydroid and coral-polyps serving as time-marks to measure off geological periods.

CLASS I.—HYDROZOA (*Hydroids and Acalephs.*)

General Characters of Hydrozoa.—An excellent idea of the general structure of the *Hydrozoa* may be obtained from a study of *Hydra*, the type or example of the whole class, all the other forms being but a modification and elaboration of this simple type. The characters of the class as a whole are based on what is found to constitute the structure of Hydra.

Order 1. *Hydroidea.*—The animal next higher in structure than the sponge is the curious *Protohydra* discovered by Greef among diatoms and sea-weeds at Ostend. It is regarded by Greef as the marine ancestral form of the Cœlenterates. It is the simplest Cœlenterate yet discovered. As the form of the fresh-water *Hydra* is familiar, *Protohydra* may be best described as being similar to that, except that it is entirely wanting in tentacles. It is made up of two layers (an ectoderm and endoderm, no mesoderm having yet been discovered), with a mouth and stomach (gastro-vascular cavity).

A more complicated form is the fresh-water *Hydra*, which is commonly found on the under side of the leaves of aquatic plants. There are two varieties of *Hydra vulgaris* apparently common to the fresh waters of the old and new world; they are *Hydra viridis* and *fusca.* The somewhat club-shaped body consists of two layers, the inner (endoderm) lining the general cavity of the body, which serves both as mouth and stomach, as well as for the circulation of the nutritive fluid, and is called the gastro-vascular cavity. The mouth is surrounded with from five to eight tentacles, which are prolongations of the body-wall, and are hollow, communicating with the body-cavity.

Such is the general structure of the Hydra. In the ectoderm are situated the lasso-cells or nettling organs, being minute barbed filaments coiled up in a cell-wall, which may be thrown out so as to paralyze the animals serving as food. While the endoderm forms a simple cell-layer, the outer layer (ectoderm) is more complex, as just within an external simple layer of large cells is a multitude of smaller cells, some of them being thread or lasso-cells, while still within are fine muscular fibrillæ which form a continuous layer. The large cells first named end in fibre-like processes, which alone possess contractility, and are thought by Kleinenberg to be motor-nerve endings. These large cells, from combining the functions of muscle and nerve, are termed "nervo-muscle cells." The little cavities between the large endodermal cells and the muscular layer (mesoderm?) which lies next to the endoderm are filled with small cells and lasso-cells, forming what Kleinenberg calls the interstitial tissue. From this tissue are developed the eggs and sperm-cells.

The body being but slightly differentiated or set apart into special organs, the Hydra, like other low creatures, is capable to a wonderful degree of reproducing itself when artificially dissected. Trembley, in 1744, described in his famous work how he not only cut Hydras in two, but on slicing them across into thin rings, found that from each ring grew out a crown of tentacles; he split them into longitudinal strips, each portion becoming eventually a well-shaped Hydra, and finally he turned them inside out, and in a few days the evaginated Hydra swallowed pieces of meat, though its old stomach-lining had now become its skin. We shall see that not only many Hydroids, Acalephs, some Echinoderms, and many worms, may reproduce lost parts and suffer artificial dissection, but that self-division is a normal though unusual mode of reproduction among these animals, as well as in the *Protozoa,* which may also be made to reproduce by artificial division, as Ehrenberg cut an infusorian into several pieces, each fragment becoming a perfect individual.

The process of budding is but a modification of that involved in natural self-division, and it is carried on to a great extent in Hydra, a much larger number of individuals being produced in this way than from eggs. Our figure (36) shows two individuals budding out from the parent Hydra; the smaller bud (*a*) is a simple bulging out of the body-walls, the bud enveloping a portion of the stomach, until it becomes constricted and drops off, the tentacles meanwhile budding out from the distal end, and a mouth-opening arising between them, as at *c*. Budding in the Hydra, the Actinia, and, in fact, all the lower animals, is simply due to an increase in the growth *and multiplication of cells at a special point on the outside of the* body, while the asexual mode of reproduction in the *Aphis* and a few other insects results from the multiplication of cells at a particular point (the ovary) in the inside of the body. Thus *Parthenogenesis* or *Agamogenesis* is analogous to the ordinary mode of budding. Ehrenberg first showed that the Hydra reproduces by fertilized eggs. Kleinenberg describes the testis, which is lodged in the ectoderm, and which develops tailed spermatozoa like those of the higher

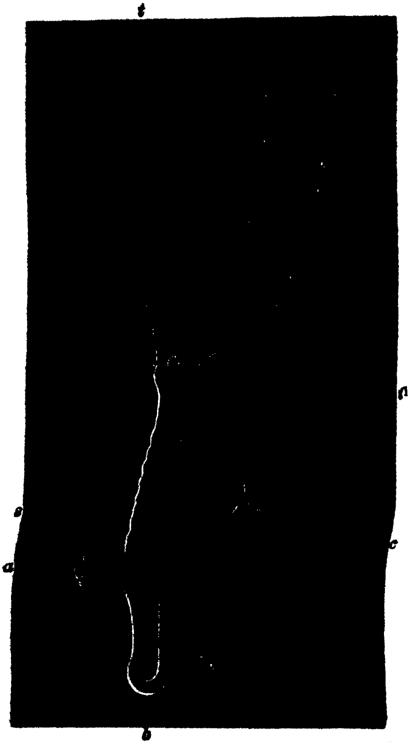


Fig. 36.—*Hydra fusca*, with two young (*a c*) budding from it; *b*, the base; *s*, the digestive cavity; *t*, tentacles.—From Clark's Mind in Nature.

animals. They arise, as in other higher animals, from a self-division of the nuclei of the testis-cells. There is a true ovary formed in the same interstitial tissue of the ectoderm, consisting of a group of cells, which, Kleinenberg states, differ entirely in their mode of formation from the ovaries (gonophores) of the marine hydroids, which are genuine buds.

It thus seems that Hydra is monœcious or hermaphrodite—*i.e.*, the sexes are not distinct. The egg of Hydra originates from the central cell of the ovary.

There is a true segmentation of the egg. The young Hydra thus passes through a true morula stage. There is an outer layer of prismatic cells, forming the surface of the germ, and surrounding the inner mass of polygonal cells. At first none of these cells are nucleated, but afterward nuclei appear, and it is an important fact that these nuclei do not arise from any pre-existent egg-nucleus.

The next step is the formation of a true chitinous shell, enveloping the germ or embryo. After this, Kleinenberg asserts that the cells of the germ become fused together, and that the germ is like an unsegmented egg, being a single continuous mass of protoplasm.

The remaining history of Hydra is soon told. In this protoplasmic germ-mass there is formed a small excentric cavity; this is the beginning of the body-cavity, which finally forms a closed sac. After several weeks the germ bursts the hard shell and escapes into the surrounding water, but is still surrounded by a thin inner shell. After this a clear superficial zone appears, and a darker one beneath, which is the first indication of the splitting of the germ into the two, afterward three, definitive germ-lamellæ, common to all animals except the one-celled Protozoa.

The embryo soon stretches itself out, a star-shaped cleft appearing, which forms the mouth. The tentacles next appear. The animal now bursts open the thin inner shell, and the young Hydra appears much like its parent form.

There is, then, no metamorphosis in the Hydra; no ciliated planula, as in many other Hydroids. The adult form is thus reached by continuous growth.

It will be seen, to anticipate somewhat, that the Hydra, exactly as in the vertebrates, including man, arises from an egg developed from a true ovary, which, after fertilization, passes through a morula stage; that the germ consists at first of two germinal layers, while from the outer layer, as probably in the vertebrates, an intermediate or nervo-muscular layer is formed, which Allman thinks is the homologue of the middle germ-lamella of the vertebrates (mesoderm) supposed to have originally split off from the ectoderm.

In all the other Hydroids the sexes are separate, and we for the first time in the animal kingdom meet with two sorts of individuals—*i.e.*, males and females.

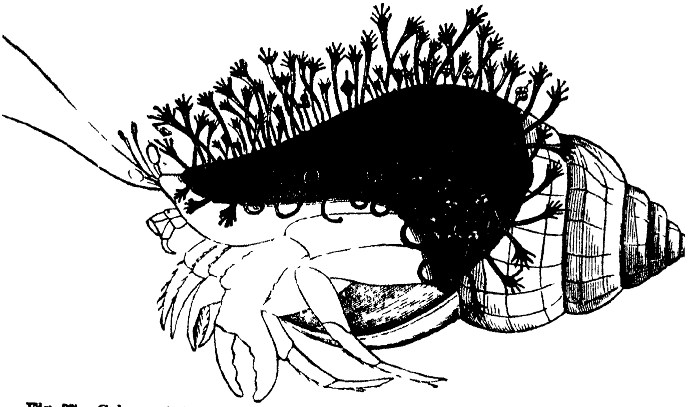


Fig. 37.—Colony of *Hydractinia echinata* on a shell tenanted by a hermit crab, natural size.—From Brehm's Thierleben.

The simplest form next to Hydra is *Hydractinia*, in which the individual is differentiated into three sets of *zooids*—*i.e.*, *a*, hydra-like, sterile or nutritive zooids; *b* and *c*, the reproductive zoöids, one male and the other female, both being much alike externally, having below the short rudimentary tentacles several spherical sacs, which produce either male or female medusæ. These medusa-buds (gonophores) are in structure like the free medusæ of *Coryne*. The marine Hydroids, then, are usually sexually distinct, growing by colonies, which are either male or female.

Hydractinia echinata (Fig. 37) forms masses (each called a hydrophyton) encrusting shells.

In *Clava* the reproductive buds remain permanently attached. It grows in pink masses on Fucoids, about half an inch high, and is very common on our shores. It is represented in fresh water by *Cordylophora lacustris* Allman, which lives attached to rocks and plants in Europe and this country.

Here comes in the group of Hydroids represented by *Millepora* and *Stylaster*, which were formerly considered to be Anthozoan corals. By the researches of L. Agassiz in 1859, and H. M. Moseley in 1876, Millepora, which had been confounded with the coral polyps, has been proved to be a Hydroid allied, as Agassiz stated, to *Hydractinia.* Like that Hydroid, it forms a calcareous encrusting mass, but of much greater extent, a considerable proportion of the coral in the Florida reefs being formed by the *Millepora.* Our American species is *Millepora alcicornis* Linn., while our description is taken from Moseley's account of *Millepora nodosa* Esper. (Fig. 38). Its generic name is derived from the numerous pores or calicles dotting its surface and arranged in irregular circular groups, consisting of a central calicle, or cup-like hollow, with from five to eight smaller calicles arranged around it. The mass of the coral, or hydrophyton, consists of fibres (or trabeculæ) of lime, forming a spongy mass, traversed in all directions by tortuous canals which "form regular branching systems with main trunks, giving off numerous branches, from which arise secondary branches, and from these again smaller

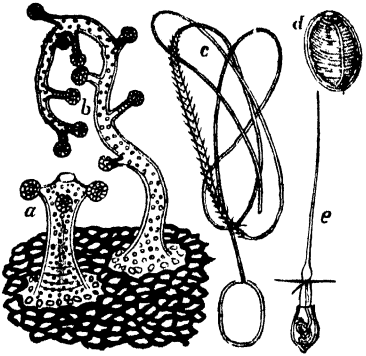


Fig. 38.—*Millepora nodosa.* *a*, nutritive zooid; *b*, reproductive zooid; *c*, lasso-cell; *d*, the same coiled up in its cell; *e*, a third form.

ramifications. The whole canal system is connected together by a freely anastomosing mesh-work of smaller vessels, and communicates freely by numerous offsets with the cavities of the calicles." As the animals increase in numbers and die, the coral stock increases in size, the layer containing the living animals forming a thin film only, the bottom of the little cups or pores forming a table or platform, whence the term *Tabulata,* originally applied to this group, the old calicles being divided by a series of transverse plates or laminæ, separating them into series of chambers. Moseley shows that the corallum of Millėpora is distinguished from all other coralla by its systems of canals branching in an arborescent manner, while the tabulate structure occurs in certain *Alcyonaria, Zoantharia,* and in other Hydroida; hence the group *Tabulata,* as previously stated by Verrill, is an artificial one.

The animals of the Millepora are of two kinds; those inhabiting the central cup or pore are short, thick zooids, with a mouth and four tentacles, and only half a millimetre in height; those in the smaller pores are longer and slenderer, about one and a half millimetres in height, with from usually five to twenty tentacles, situated at irregular intervals from the base to the summit of the body. The body cavities of the zooids end in blind sacs at the bottom of the cup, but are continuous beyond with the canals of the hydrophyton, the latter being defined by Allman as forming in the Hydroids "the common basis by which the several zooids of the colony are kept in union with one another." As we know nothing of the mode of reproduction of Millepora, we must leave it for the present near *Hydractinia,* to which the adult animals are nearest related. Moseley also discovered that *Stylaster,* a beautiful pink coral which grows at Tahiti, with the Millepora, is in reality a Hydroid, and not a true coral polyp, as has always been supposed. That, finally, Millepora is a true Hydroid is proved, Moseley thinks, by the peculiar structure of the hydrophyton, the forms of the zooids, the absence of all trace of mesenteries, the apparent septa present in the tentacles, and by the presence of thread-cells of the form peculiar to the *Hydrozoa.* The living Millepora, unless handled with great care, severely stings the hand of the collector.

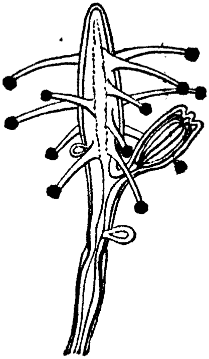


Fig. 39. — Polypite of *Coryne mirabilis*, with a bud below *a*, and medusa-bud (gonophore) at *a*. Much enlarged.—After Agassiz.

We now come to Hydroids which throw off a free naked-eyed medusa from the hydrarium (Fig. 39). From the centre of these free bell-shaped, minute jelly-fishes depends a hollow, open sac called the *manubrium*, the cavity of which (stomach) opens into usually four canals, which radiate from the hollow or stomach in the centre of the disk and communicate with a canal following the margin of the disk. This is the water-vascular system, communicating directly with the gastro-vascular cavity, or stomach. Four tentacles hang from the disk, and simple eye-spots and otolithic sacs (simple ears) are usually present and situated at regular intervals around the edge of the disk. Such is the typical form of all the free-swimming Hydroids. They are said, in a few cases, to possess a well-developed continuous nervous system, consisting of a nervous ring around the disk (Romanes). They are bisexual, the ovaries or spermaries being developed on the radiating canals, the embryo escaping into the surrounding water by rupturing the walls of the ovary.

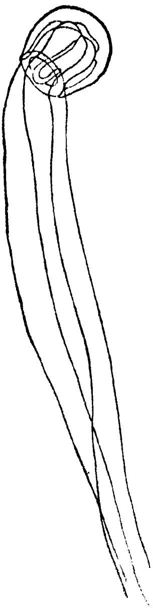


Fig. 40.—Free Medusa of *Coryne*.

The young is at first oval, ciliated all over the surface of the body, and is called a *planula*. The planula, as in *Melicertum*, a genus allied to *Campanularia*, and a type of most marine Hydroids, at first spherical, becomes pear-shaped, and after swimming about for a time attaches itself to some object. It then elongates, a horny sheath (*peri-*

sarc) forms around it, tentacles arise around the mouth, finally the stem branches, new Hydroids arise, until a hydroid community (consisting of *trophosomes* and *gonosomes)* is formed, and in the following spring medusa-buds (gonophores) arise, which become free (medusoids), and thus the reproductive cycle is completed. The developmental history of this Hydroid is a good example of what is called "alternation of generations."

Budding occurs in the medusa of *Sarsia prolifera,* in *Hybocodon prolifer* and *Dysmorphosa fulgurans.* Multiplication by fission has been observed in the medusa of *Stomobrachium mirabile.* The pendent stomach was seen by Kölliker to divide in two, becoming doubled, which act was followed by a vertical division of the umbrella, separating the animal into two independent halves. These again subdivided, and Kölliker thinks this process went on still further. Haeckel has found in cutting off a portion of the edges of the umbrella of certain *Thaumantiæ,* that the fragment in a few days became a complete medusa.

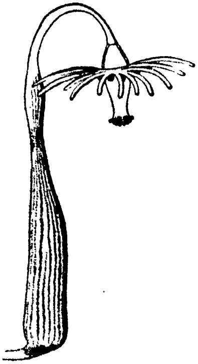


Fig. 41.—*Monocaulus pendulus.*—After Agassiz.

In the Tubularian Hydroids (*Tubularia, Hybocodon, Corymorpha, Monocaulus,* etc., Fig. 41), the mode of reproduction is peculiar. From the medusa-buds (sporosac) is set free an embryo (actinula), which swims about or creeps on its tentacles, mouth downward. It then attaches itself by a disk-like expansion of the posterior end, which forms a stem until the original Tubularia form is attained.

A gigantic *Monocaulus* having sessile ovisacs, measuring seven feet four inches in height, and provided with a crown of tentacles nine inches across from tip to tip of the expanded, non-retractile tentacles, was dredged by the Challenger Expedition at the depth of four miles. Allman suggests that such a deep-sea Hydroid could not, on account of the darkness and pressure of the water at such a great depth, produce free-swimming medusæ. In *Tiaropsis* there is no trace of a nervous system such as exists in *Sarsia,* where nerve-fibres extend around the margin and along the radial tubes (Romanes).

In the groups of *Campanulariæ,* represented by *Plumularia, Sertularia, Zygodactyla, Dynamena,* and *Campanularia,* the ectoderm is protected by a horny or chitinous sheath (perisarc) enveloping the zooids. The Hydroids retract, when disturbed, into small cells (hydrothecæ), arranged in opposite rows on the stalk as in *Sertularia* (Fig. 42), or singly at the ends of the stalks, as in *Campanularia,* while the sheaths (*gonothecæ*) protecting the medusa-buds are distinguished by their much larger size and cup-shaped form.

The Sertularians abound on sea-weeds, and may be recognized from their resemblance to mosses. They are among the most common objects of the seaside. The medusæ of these and many other Hydroids can be collected by a towing-net, and emptied into a jar, where they can be detected by the naked eye after a little practice.

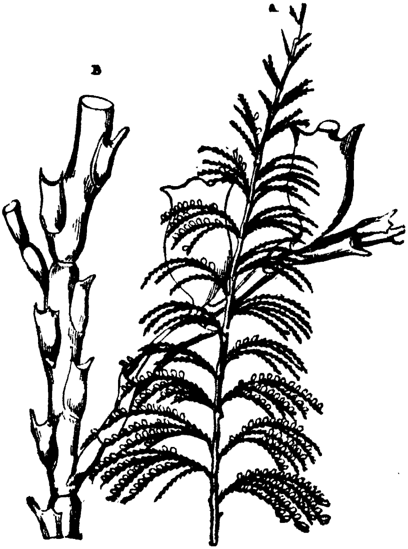


Fig. 42.—*Sertularia abietina* of Europe. *A*, natural size; *B*, magnified, showing the hydrarium, with the cells.—From Macallister.

Graptolites.—More nearly allied perhaps to the Sertularian Hydroids than any other known animals are the Graptolites (Fig. 43), which were most abundant in the Lower Silurian period, and lingered as late as the Clinton epoch of the Upper Silurian. In *Graptolithus Logani* the hydroid colony (hydrosome) is a long narrow blade, with a row of cells on one

Order 2. Discophora.—We now come to medusæ which differ from the Hydromedusæ in *developing directly from eggs; in having usually no velum; with* branching gastro-vascular canals, and covered sense-organs. They intergrade, however, with the Hydroidea by the members of the group or sub-order *Trachymedusæ,* represented by the genera *Ægineta, Geryonia,* etc. These are small jelly-fishes, with often a remarkably long proboscis (*manubrium*), as in *Geryonia,* and with either four single radiating canals, or, in addition, as in *Geryonia,* a number of smaller canals on the edge of the disk; or, as in a still more complicated form, *Charybdæa,* the radiating canals are branched, thus connecting this group with the true covered-eyed Acalephs, such as *Aurelia.*

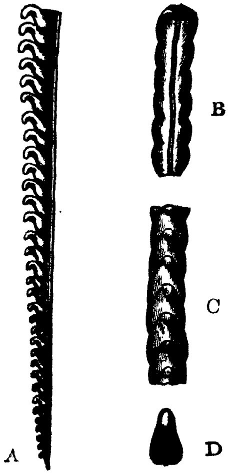


Fig. 48.—*Monograptus priodon.* *c*, front view.—After Nicholson.

O. and R. Hertwig have fully confirmed Haeckel's discovery of the nature of the nervous system in the *Geryonidæ.* They find that the nervous system is developed in the ectoderm and consists of two "ring-nerves" around the edge of the disk, formed of two filaments, one lying on the upper, the other on the under side of the velum, immediately at its insertion. From this double nervous ring filaments are sent off to the ganglia near the sense-organs. This sort of a nervous system is present in the *Æquoridæ* and *Æginidæ*, but is most distinct and best developed in the *Geryonidæ* (*Glossocodon* and *Carmarina*).

The Hertwigs have also observed in these Trachynemidæ organs of taste, consisting of groups of long stiff hairs at the base of the tentacles. They have been observed in *Rhopalonema velatum*, *Aglaura nemistoma*, and in *Cunina*, where the hairs are shorter.

The eggs, in developing, after total segmentation (morula state) pass into a ciliated planula state as in *Aurelia*, there being at first apparently no primitive gastric cavity; the body of the embryo or planula remains spherical, as in *Geryonia*, there being a slight metamorphosis; or, as in *Polyxenia* and *Æginopsis*, where there is a decided metamorphosis, the spherical ciliated planula greatly lengthens out on each side, the body becoming boomerang-shaped, each end of the boomerang becoming an arm or tentacle. Then it becomes a gastrula, a central cavity and mouth appearing. At right angles to the two primitive arms bud out two others, and finally others appear on the lower edge of the umbrella, and after slight changes the adult form is assumed. *Cunina* is at first spherical, then, a single arm developing, it becomes club-shaped; finally, the full number of arms grow out, and the mature form results. It appears, then, that in the mode of development from eggs, without passing through a hydra-like condition, and in the structure of the body, the *Trachymedusæ* connect the covered-eyed medusæ with the naked-eyed or *Hydroidea*. The American forms live in the waters of the Carolina shores. *Cunina octonaria* McCrady lives in Charleston Harbor. *Cunina* has been found by Haeckel growing on the columella of *Geryonia*, and McCrady has found that our native *Cunina* is parasitic on *Turritopsis*, a hydroid medusa.

The *Lucernariæ*, or *Calycozoa*, which, according to Clark, form an order of Acalephs, are, with Huxley, regarded as a suborder of *Discophora*. With essentially the structure of the Aurelia and allies, *Lucernaria* differs in having the power of attaching itself by a sucker on the smaller end of its body to sea-weeds, but can detach itself at will and swim about like the *Aurelia* by alternate contractions and expansions of the umbrella. We will now enter into a more complete account of this group based on Clark's characterization. The disk is more or less octagonal or circular, umbrella, funnel or urn-shaped, the end opposite the mouth ending in a pedicel, by which it is attached temporarily to sea-weeds. The mouth is square, and between the ectoderm and endoderm is a jelly-like layer constituting the musculo-gelatiniform layer (mesoderm) much as in *Aurelia.* This layer extends into the tentacles and marginal anchors, as well as into the pedicel. The cavity of the disk is divided into four quadrant chambers, separated by as many partitions, which extend from the mouth into the lobes nearly to the margin between the tentacles. The latter are arranged in eight groups or tufts just within the margin of the disk, at eight points, which alternate with the four partitions and the four corners of the mouth. The tentacles are hollow, opening into the radial canals of the general cavity of the body, and end in a globular or spheroidal expansion, serving as an organ of touch or prehension. In some forms, as *Haliclystus auricula* Clark, marginal anchors are situated at eight points, exactly opposite the four partitions and the four corners of the mouth ; they are originally tentaculiform, but in adult life form organs by which they adhere to or pull themselves from place to place. The sexes are distinct, the reproductive glands having the same position in each sex. Nothing is absolutely known of the mode of growth of these animals, but development is supposed to be direct. Our common Lucernarian is *Haliclystus auricula* Clark. Its umbrella-shaped disk is an inch in diameter ; including the tentacles, an inch and a half ; the pedicel half an inch long. It ranges from Cape Cod to Greenland and southward to the coast of England, and may be found on eel-grass between tide-marks.

According to A. Meyer, the end of the stalk when cut off produced a new disk, and even pieces cut off between them became complete *Lucernariæ,* evincing the extraordinary powers of reproduction in these interesting jelly-fish.

Coming now to the true Discophora, jelly-fish, seanettles, sun-fish or Acalephs, of which there are about ninety known species on the eastern coast of the United States, we may study as the type of the suborder the common *Aurelia flavidula* Péron and Lesueur of our coast, which is closely allied to the *Aurelia aurita* of the European shores. It grows to the diameter of from eight to ten inches, becoming fully mature in August, the young appearing late in April in Massachusetts Bay, being then not quite an inch in diameter. The mature ones may be easily captured from a boat or from wharves. On a superficial examination, as well as by cutting the animal in halves and making several transverse sections with a knife, the leading points in its structure may be ascertained. Its tough, jelly-like disk is moderately convex and evenly curved, while four thick oral lobes depend from between the four large genital pouches; the oral lobes unite below, forming a square mouth-opening, the edge of which is minutely fringed to the end of the tentacles. On the fringed margin are eight eyes, each covered by a lobule and situated in a peduncle, and occupying as many slight indentations, dividing the disk into eight slightly marked lobes. The subdivisions of the water-vascular canals or tubes are very numerous and anastomose at the margin of the disk, one of them being in direct communication with each eye-peduncle. When in motion the disk contracts and expands rhythmically, on the average twelve or fifteen times a minute; on the approach of danger they sink below the surface.

While a distinct nervous system has not been discovered in Aurelia, Romanes suggests that there are primitive nervo-muscular cells, such as those shown by Kleinenberg to exist in Hydra, and he concludes, after a series of experiments on *Aurelia aurita*, that the whole contractile sheet of the bell presents not merely the protoplasmic qualities of excitability and contractility, but also the essentially nervous quality of conducting stimuli to a distance irrespective of the passage of a contractile wave. The later researches of O. and R. Hertwig show that the nervous system of Acalephæ (Acraspedota or covered-eyed Medusæ) is much more primitive than in the naked-eyed or craspedote forms, such as the medusæ of the Hydroids and the *Trachynemidæ.* In the European *Nausithoe albida* and *Pelagia noctiluca* no nerve-ring is present, for this is impossible owing to their deeply indented disks. There are instead eight separate nerve-tracts which unite with the sense-organs in a special elevation of the edge of the disk, forming so-called sense-bearers, which alternate with the eight tentacles. *Aurelia aurita* has a similar disconnected nerve system.*

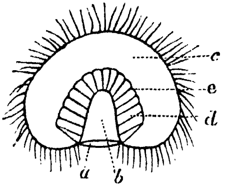


Fig. 44.—Gastrula of an Aurelia-like *Medusa.* *a*, primitive mouth; *b*, gastro-vascular cavity; *c*, ectoderm; *d*, endoderm.—After Metschnikoff.

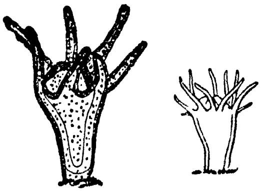


Fig. 45.—Scyphistoma of *Aurelia flavidula*, at different ages; magnified.—After Agassiz.

Eimer confirms these discoveries, and states that the nervous system in these Hydrozoa arises from the ectoderm.

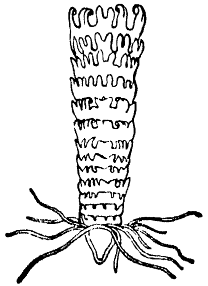


Fig. 46.—Strobila of *Aurelia flavidula.* — After Agassiz.

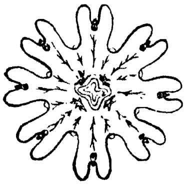


Fig. 47. — Ephyra or earliest free condition of *Aurelia.*—After Agassiz.

The *Aurelia flavidula* spawns in late summer, the females being distinguishable by their yellowish ovaries, the male glands being roseate, while the tentacles of the females are shorter and thicker than in the males. The eggs pass out of the mouth into the water along the channeled arms, and in October the ciliated gastrula becomes pear-shaped and attaches itself to rocks, dead shells, or sea-weeds, and then assumes a Hydra form with often twenty-four very long tentacles. This stage was originally described as a distinct animal under the name of *Scyphistoma.* In this Scyphistoma stage (Fig. 45) it remains about eighteen months. Toward the end of this period the body increases in size and divides into a series of cup-shaped disks. These saucer-like disks are scalloped on the upturned edge, tentacles bud out, and the animal assumes the Strobila stage (Fig. 46). Finally, the disks separate, the upper one becomes detached and with the other disks swims away in the *Ephyra* form (Fig. 47), when about a fifth of an inch in diameter, and toward the middle or end of summer becomes an adult *Aurelia* (Fig. 48).

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* Jenaische Zeitschrift, 1877, p. 355.

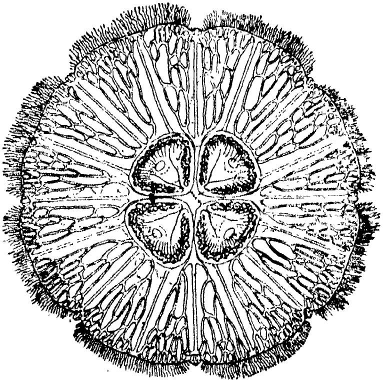
Fig. 48.—*Aurelia flavidula.*—After Agassiz.

Though the Aurelia has lasso-cells it is not poisonous to bathers. Not so, however, with the gigantic *Cyanea arctica,* whose long tentacles are poisonous ; fishermen as well as bathers being often annoyed by them. This giant jelly-fish sometimes attains a diameter of from three to five feet across the disk, though it is produced from a Scyphistoma not more than half an inch in height. *Pelagia campanella* and a few other forms do not undergo this metamorphosis, but grow directly from the eggs.

Various boarders or commensals—viz., temporary non-attached parasites—live in or under the mouth-cavity or between the four tentacles of the larger Acalephs. Such is the little Amphipod Crustacean, *Hyperia*, which lives within the mouth, while small fishes, such as the butter-fish, swim under the umbrella of the larger jelly-fishes, *Cyanea*, etc., for shelter and protection. Besides small animals of various classes, the larger jelly-fishes kill by means of their nettling organs small cuttle-fishes and true fishes, the animals being paralyzed by the pricks of the minute barbed darts.

Order 3. *Siphonophora.*—These are so-called compound Hydroids, living in free-swimming colonies, consisting of polymorphic individuals, or, more properly speaking, *zooids* —that is, organs with a strongly marked individuality, but all more or less dependent on each other. A Siphonophore, such as *Physalia*, for example, may be compared to a so-called colony of *Hydractinia*, in which there are nutritive and reproductive zooids and medusa-buds. In Physalia there are four kinds of zooids—*i.e.* (1) locomotive, and (2) reproductive, with (3) barren medusa-buds (in which the proboscis is wanting), which, by their contractions and dilatations, impel the free-swimming animal through the water; in addition, there are (4) the feeders, a set of digestive tubes which nourish the entire colony. There are numerous genera and species (one hundred and twenty are known), whose structure is more or less complicated and difficult to understand without many figures and labored descriptions. We will select as a type of the order our *Physalia Arethusa* of Tilesius, or Portuguese man-of-war (Fig. 49), which is sometimes borne by the Gulf Stream as far north as Sable Island, Nova Scotia. It is excessively poisonous to the touch, and in gathering specimens on the shores of the Florida reefs we have unwittingly been stung by nearly dead, stranded individuals, whose sting burns like condensed fire and leaves a severe and lasting smart.

The colony or hydrosome of the Portuguese man-of-war consists of long locomotive tentacles, which, when the animal is driven by its broad sail or float before the wind, stretch out in large individuals from thirty to fifty feet. These large Hydra-like zooids are arranged in small groups, arising from a hollow stem communicating with the chymiferous cavity extending between the inner and outer wall of the float. The "feeders" are of two kinds, large and small, and are clustered in branches growing from a common hollow stem, also communicating with the chymiferous or body-cavity. L. Agassiz, whose description of this animal we are condensing, states that he has seen these feeders "gorged with food almost to bursting," but has never seen undigested food in any of the other organs. The medusa-buds (gonophores) arise from a third set of very small Hydras, but form very large clusters suspended between the clusters of feeders. These reproductive zooids resemble the locomotive zooids, but, like the feeders, have no tentacles. The medusa-buds, which are male or female, arise singly, either from the base of the reproductive zooids or from the stems which unite the latter. These buds, as in *Tubularia,* wither without dropping from their parent stock. It appears, then, that the floating hydrosome of a Siphonophore is like that of the fixed *Hydractinia* or *Coryne,* with the addition of locomotive zooids and a float, as seen in *Physalia, Velella,* or the swimming-bells of *Halistemma.*

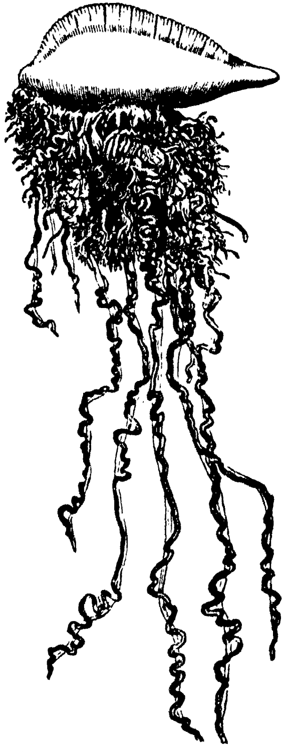

Fig. 40.—*Physalia,* or Portuguese man-of-war.—After Agassiz.

The Siphonophores, as observed in *Agalma*, *Epibulia*, *Agalmopsis*, and other forms, arise from eggs which pass through a morula, planula, and gastrula stage. The further development of *Agalmopsis elegans*, a Siphonophore native to the shores of New England, has been described by A. Agassiz as follows : In the earliest stage noticed the young looked like an oblong oil-bubble, with a simple digestive cavity. Soon between the oil-bubble and the cavity arise a number of medusa-buds, though without any proboscis (manubrium), since the medusa-buds are destined to form the "swimming-bells," which take in and reject the water, thus forcing the entire animal onward. After these swimming-bells begin to form, these kinds of Hydra-like zooids arise. In one set the Hydra is open-mouthed, and is, in fact, a digestive tube ; its gastro-vascular cavity connecting with that of the stem, and thus the food taken in is circulated throughout the community. These are the so-called "feeders." The second set of Hydras differ only from the feeders in having shorter tentacles twisted like a corkscrew. In the third and last set of Hydras the mouth is closed, and they differ from the others in having a single tentacle instead of a cluster. Their function has not yet been clearly explained. New zooids grow out until a long chain of them is formed, which moves gracefully through the water, with the float uppermost.

All the Hydroids in their free state as medusæ are more or less phosphorescent, and as much or more so after death, when their bodies become broken up, and the scattered fragments light up the waves whenever the surface of the ocean is agitated. From this cause the sea is especially phosphorescent in August and September, when the jelly-fishes are dying and disintegrating. These creatures serve as food for the whalebone whales, which swallow them by shoals.

The smaller species are abundant in the circumpolar seas, while in the tropics the Siphonophores are especially numerous, none occurring in the Arctic regions. The Hydroids are widely distributed, a species of Campanularia being common to the Arctic and Antarctic seas. The species occurring on the New England coast are in many cases found in Northern Europe, being circumpolar in their range. A distinct assemblage of Sertularians, characterized by the large number of species of *Plumularia*, inhabits the Florida seas down to a depth of five hundred fathoms. Among the Discophora the Lucernariæ are arctic as well as temperate forms, while *Cyanea* is peculiar to the Northern Hemisphere. *Aurelia* and *Pelagia* are cosmopolites, while *Rhacopilus*, *Placoïs*, and *Lobocrocis* are peculiar to the Southern Hemisphere. The larger number of species are tropical and sub-tropical. As regards their bathymetrical distribution, while several species extend to the depth of five hundred fathoms, *Monocaulus* flourishes in gigantic proportions at the enormous depth of four miles.

The range in geological time of the *Discophora* extends to the Jurassic period (middle Oolitic), large species of jelly-fishes occurring in the Solenhofen slates. The genus *Hydractinia* first appeared in the Cretaceous period. Graptolites were common in the shales of the Potsdam period, so that if Graptolites are Acalephs, the latter are probably as old a type as any, being contemporaneous with trilobites, brachiopods, mollusks, worms and sponges.

CLASS I.—THE HYDROZOA.

Body in its simplest form a sac attached by the aboral end, composed of three cell-layers, with a mouth and gastro-vascular cavity, and in all cases, except Protohydra, provided with tentacles, which are hollow, forming continuations of the body-cavity. The body (hydrosome) usually differentiated into two sorts of zooids, nutritive (polypites) and reproductive (gonosomes), connected by a common stem or nutritive canal (cœnosarc), the gonosomes producing medusa-buds (gonophores), which on being set free are called medusæ (or medusoids) and are bisexual. In these medusæ the body is disk or bell-shaped, the jelly-like parenchymatous substance composing the disk constituting the mesoderm. From the gastro-vascular cavity four primary gastro-vascular canals radiate and anastomose with a marginal circular canal. No distinct organs of circulation, the blood being sea-water containing the chyme and a few colorless blood-corpuscles. A true nervous system rarely present, but when developed in certain medusoids, forming a*

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* Agassiz saw in Rhizogeton, a form allied to Hydractinia, a gonophore which had discharged its contents, degenerating into a polypite or hydra, and its body elongating and developing tentacles. Allman observed the same thing in Cordylophora.

thread-ring around the disk, and with ganglia near the sense-organs. In Hydra the nervous system is represented by nervo-muscle cells; sense-organs usually present, represented by simple eyes and auditory vesicles (lithocysts), the two not usually coexisting. Nettling organs (nematocysts) usually present, and especially characteristic of the class, being most abundant on the tentacles.

The sexes rarely united, usually distinct. Often a high degree of polymorphism in the individual hydrosome, the animal being differentiated not only into polypites and gonosomes, but, in the free-swimming forms, into locomotive zooids. Reproduction takes place by budding, and by fertilized eggs developed in glands attached to or dependent from the primary radiating canals. The species undergo either a slight or marked metamorphosis, the free gonophores being medusæ (or medusoids), which produce eggs, from which in some Discophora (such as Aurelia) arise successively a morula, gastrula, planula, scyphistoma, strobila, and adult medusa, representing distinct stages of growth.

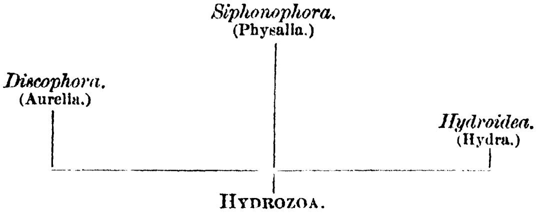
Order 1. *Hydroidea.* — The individual either not differentiated into zooids, as in *Protohydra* and *Hydra*, or consisting of nutritive and reproductive zooids forming a compound, stationary, branching, moss-like body (hydrosome), the medusa-buds remaining on the gonosomes or becoming free medusæ, with usually four simple radiating canals, a velum, manubrium, and naked eyes. Hydrosome either naked or as in *Sertularia*, etc., protected by a horny sheath, or forming, as in *Millepora* and *Heliolites*, a massive corallum. Suborder 1. *Tubulariæ* (Hydra, Clava, Hydractinia, Millepora, Tubularia). Suborder 2. *Campanulariæ* (Plumularia, Dynamena, Campanularia, Æquorea, Zygodactyla).

Order 2. *Discophora.*—Medusæ like those of the Hydroids, but with the four primary radiating canals usually subdividing into numerous branches, the eyes more or less covered by a flap; the velum often absent; often four genital pouches, discharging eggs into the gastro-vascular cavity; usually of large size, and developing either directly from eggs, or, as in *Aurelia*, passing through a gastrula, scyphistoma, and strobila stage, not being developed from a hydra-like polypite. Suborder 1. *Trachymedusæ* (Ægina, Cunina, Geryonia, Charybdæa). Suborder 2. *Lucernariæ* (Lucernaria). Suborder 3. *Acalephæ* (Pelagia, Cyanea, Aurelia, Rhizostoma).

Order 3. *Siphonophora.* —Free-swimming, polymorphic hydrosomes, with nutritive, feeding, reproductive and locomotive zooids. Suborder 1. *Physophoræ* (Agalma). 2. *Physaliæ* (Physalia). 3. *Calycophoræ* (Diphyes). 4. *Discoideæ* (Velella, Porpita).

NOTE.—*Stephanocyphus mirabilis* Allman is the type of a new order of Hydrozoa called by Allman *Thecomedusæ*. The animal permeates and is parasitic in sponges. Although a Hydrozoan, it is not a Hydroid, and cannot be referred to any of the existing orders of the Hydrozoa. The chitinous tubes which permeate the sponge-tissue are united toward the base of the sponge, and constitute a colony of zooids. In many respects it is said to resemble the *Campanulariæ*.

VIEW OF THE CLASSIFICATION OF THE HYDROZOA.



Laboratory Work.—The common Hydroids, such as *Coryne*, *Sertularia*, etc., may be collected from sea weeds or the piles of wharves between tide-marks, while the medusæ may be obtained by the hand-net, or tow-net from a boat. The medusæ especially abound in eddies off points of land where different currents of the sea meet. Towing is most effectively pursued after sunset and early in the evening, when the sea is calm, and the jelly-fish swim near the surface. They should be placed in the jars by inverting the net in the water of the jar, and examined at once, as many will have perished by the next morning. Jelly-fish can also be reared in roomy aquaria, in which plenty of air is introduced by running water.

The larger medusæ, such as *Aurelia* and *Cyanea*, should be sliced in sections in order to study their gross anatomy, and portions snipped off with scissors to be examined with the microscope. The animals of Sertularians, Coryne, etc., can be studied alive in animalcule-boxes and growing-cells. The coral stock of Millepora was examined by Moseley in ground sections. "Portions of the living coral were placed in absolute alcohol, chromic acid, and glycerine; portions were further treated with osmic acid and transferred to glycerine or absolute alcohol. Fragments of the hardened coral were afterward decalcified with hydrochloric acid, and the residual soft structures were either mounted entire for examination, or cut in the usual manner into fine vertical and horizontal sections, which were then stained with carmine or magenta. The specimens hardened in osmic acid, and decalcified after subsequent immersion in absolute alcohol, yielded the best histological results."

While the jelly-fishes should be studied alive, the larger ones can be preserved in alcohol, after being killed by the gradual addition of alcohol to the sea-water in which they are living. The small medusæ, as well as *Noctiluca* and the Ctenophores, have been preserved with success by E. Van Beneden, by the use of a solution of osmic acid or of picric acid. Osmic acid hardens the tissues so that fine sections can be made, and it colors black the greasy matters, and especially myeline, a chemical substance usually found in the nervous system, and enables us to trace well the limits of the cells. The small jelly-fishes may be placed in a very weak solution of osmic acid ($\frac{1}{8}$ to $\frac{1}{10}$ per cent. of water) varying with the size of the animal, for from fifteen to twenty-five minutes, when the animal turns brown. This brings out clearly the gastro-vascular canals. The specimen can then be placed in strong alcohol, without losing its form and transparence. These animals and all other transparent animals can be well kept in a concentrated, watery solution of picric acid. Professor Semper tells us that all soft animals, worms as well as hydroids and polyps and mollusks, may be killed expanded in chromic acid (1½ per cent), or in acetic acid of variable strength, and then preserved in alcohol.

CLASS II.—THE ACTINOZOA (*Sea-Anemones and Coral Polyps*).

General Characters of Actinozoans.—So persistent is the form and structure of the body in these animals, that a study of the common sea-anemone will enable the student to readily comprehend the leading and most fundamental characteristics of the class.

The common Actinia of our coast (*Metridium marginatum*) is to be found between tide-marks on rocks under sea-weeds, or in tidal pools, but grows most luxuriantly on the piles of bridges. It readily lives in aquaria, where its habits may be studied. An aquarium may be improvised by using a preserve-jar or glass globe, covering the bottom with sand, with a large flat stone for the attachment of the sea-anemone. By placing a green sea-weed (ulva) attached to a stone in the jar, and filling it with sea-water, the animal may be kept alive a long time. After observing the movements of the crown of tentacles as they are thrust out or withdrawn, specimens may be killed expanded by the gradual introduction of fresh water, or by plunging them into picric acid. They should then be transferred to the strongest alcohol, and allowed to soak in it for two or three days until the tissues become hard enough to cut well. Then vertical and transverse sections may be made with a sharp knife. The first fact to observe is, that an alimentary canal is much more clearly indicated than in the *Hydrozoa*, there being a distinct digestive sac, separate from the body-walls, hanging suspended from the mouth-opening, and held in place by six partitions or septa (mesenteries), which divide the body-cavity into a number of chambers. The digestive sac is not closed, but is open at the bottom of the body, connecting directly with the chambers, so that the chyme, or product of digestion, passes down to the floor of the body, and then into each of the chambers; thus, by the movements of the cilia lining the body-cavity, the chyme, mixed with the blood, is distributed throughout the body; this rude mode of circulation being the only means of distribution of the nourishment contained in the circulating fluid, there being no distinct canals, as in the *Hydrozoa*. These mesenteries may be best studied in a cross-section of the animal after being hardened. It will be found that there are six pairs of complete or primary septa or partitions (mesenteries) which hold the stomach in place, and a number of pairs of shorter ones of unequal length between the complete ones. There are never less than twelve of the secondary partitions, even in the young, and when more numerous they occur in multiples of six (Clark). On the free edges of these shorter mesenteries, which do not extend out to the stomach, there is a mass of long coiled filaments, the mesenterial filaments (*crăspeda*, Fig. 50, *cr*), which contain lasso-cells, situated in a peripheral layer, while the filament is hollow and contains *guanin*. In dissecting the sea-anemone these mesenterial filaments are always more or less in the way, and have to be carefully removed so as to expose the ovaries and adjoining parts. They press out of the mouth and the *cinclides* (small openings through the body-walls), not always present, and end of the tentacles, and thus come in contact with animals forming their food. The ovaries and spermaries can be distinguished by their forming masses of closely convoluted tubes much thicker than the mesenterial filaments, and situated on the outside next to the free edge of each mesentery ; they are also of a pale lilac tint in *Metridium marginatum* (Fig. 50, *o*). They are not easily distinguishable from each other by the naked eye. The figure shows at the base of the body the free edges of the mesenteries (*m*) of different heights, with the spaces between them through which the chyme passes into the body-cavity. For the complete passage of the circulating fluid the six primary mesenteries are perforated by a large orifice (*op*) more or less oval or kidney-shaped in outline (Fig. 50). The digestive sac is divided into two divisions, the mouth and stomach proper, the latter when the animal is contracted being much shortened, and with the walls vertically folded, as seen in the cut.

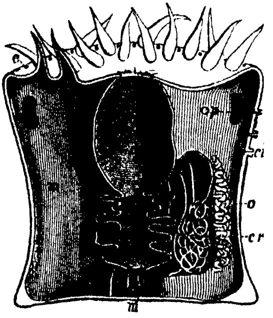


Fig. 50.—Partly diagrammatic sketch of the anatomy of an Actinia (***Metridium***) with the tentacles disproportionately enlarged. *s*, stomach ; ***m***, mesenteries, or septa ; *o*, ovary ; *ci*, cinclis ; *cr*, mesenterial filaments; *e*, eyes; *op*, orifice through the septa.—Drawn by J. S. Kingsley, under the author's direction.

In the tentacles are lodged the lasso-cells or nematocysts, and the tentacles are hollow, communicating directly with a chamber or space between the mesenteries, and are open at the end. When a passing shrimp, small fish, or worm comes in contact with these tentacles, the lasso-cells are thrown out, the victim is paralyzed, other tentacles assist in dragging it into the distensible mouth, where it is partly digested, and the process is completed in the second or lower division of the digestive canal. The bones, shells, or hard tegument of the animals which may be swallowed by the Actinia are rejected from the mouth after the soft parts are digested. Pigment-cells, which are supposed to be liver-cells, are said to be situated in the walls of the stomach, and the mesenterial filaments have been supposed to act as kidneys in taking up and excreting the waste products of digestion, but this has not been proved and seems improbable. The blood, or sea-water, mixed with particles of food ("chylaqueous fluid"), the result of digestion, was supposed by Williams to represent the chyle of higher animals and to contain white blood-corpuscles, but this has been denied by Lewes ("Sea-side Studies") on apparent good grounds. Bilateral or right and left symmetry is faintly indicated in the young and old Actinia, as well as in some corals, as pointed out by Clark.

While no true nervous system is known to exist in the *Actinozoa*, Duncan has discovered in the base of the body a plexus of fusiform ganglionic cells connected by nerve-fibres. Isolated nerve-cells have been discovered by Schneider and Rötteken near the pigment-cells or supposed eyes at the base of the tentacles of the Actinia. In connection with these nerve-cells are certain round refractive cells (Haimean bodies) and other long cells, called the Rötteken bodies. The former are thought by Professor Duncan to carry light more deeply into the tissues than the ordinary epithelial cells. This is also the case with the elongated Rötteken cells and others similar to them, called *bacilli*. All these, when brought together in this primitive form of eye, "concentrate and convey light with greater power, so as to enable it to act more generally on the nervous system probably not to enable the distinction of objects, but to cause the light to stimulate a rudimentary nervous system to act in a reflex manner on the muscular system, which is highly developed." (Duncan.)

Nearly all the Actinozoa increase by budding, new individuals arising at the base or edge of the pedal disk of the old ones. Clark has seen in *Metridium marginatum* as many as twenty buds separate from the parent sea-anemone. "As in Hydra they arise as simple rounded protuberances, but in a short time six short tentacles make their appearance at the free end, and a minute oblong aperture, the mouth, is found in their midst in such a way that its two ends have a tentacle opposite each, and the other four disposed two on one side and two on the other. Within, the organs arise at points corresponding to the position of those outside. The semi-partitions, twelve in number, begin as mere ridges, which extend in pairs from the anterior end of the stomach along the oral wall toward its border." Adult Actiniæ sometimes, though rarely, subdivide longitudinally, but it is not uncommonly observed in the corals, in which cases only the heads and stomachs divide, the general cavity remaining common to the two.

The development of *Actinia mesembryanthemum* has been traced by Lacaze-Duthiers. The young Actinia attains maturity without any metamorphosis. The egg is supposed to undergo segmentation within the ovary. In the state in which the embryo was observed by Lacaze-Duthiers it was oval and surrounded by a dense coat of transparent conical spinules. Soon the two primitive germinal layers (ectoderm and endoderm) were observed. Two lobes next appear within the body; these subdivide into four, eight, and finally twelve primitive lobes. This stage is represented by the corresponding stage of the coral (Fig. 55, *B*). Not until after the twelve primitive lobes are fully formed do the tentacles begin to make their appearance. When the first twelve tentacles have grown out, twenty-four more arise, and so on, until with its increasing size the Actinia is provided with the full number peculiar to each species. Lacaze-Duthiers observed the same changes in two species of *Sagartia*, and in *Bunodes gemmacea*. Fig. 51 represents the ciliated gastrula of an unknown polyp allied to *Kalliphobe*. While *Metridium* and *Bunodes* are types of the ordinary form of Actinoids, certain forms, like *Halcampa producta* Stimpson (Fig. 52), are quite long and live fixed in the mud or sand. Allied to *Halcampa* is *Edwardsia*, which

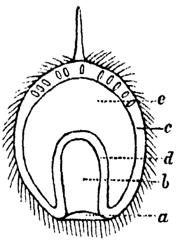


Fig. 51.—Ciliated larva (gastrula) of a Polyp. *a*, primitive opening or blastopore; *b*, stomach; *c*, [illegible] ectoderm, *d*, endoderm. —After Metschnikoff.

lives in deeper water. Its young, however, is at an early stage of its existence a free-swimming polyp, which was originally described as an adult animal under the name of *Arachnactis*. In *Zoanthus* the tegument is tough and leathery, and the different polyps are connected by stolons. *Epizoanthus americanus* Verrill lives in deep water, off the coast of New Jersey and Southern New England, in about twenty fathoms. *Cerianthus*, a gigantic form, a native species of which (*C. borealis* Verrill) lives at the depth of one hundred fathoms in the Gulf of Maine deeply sunken in the mud, where it secretes a shiny leathery tube, is perforated at the end of the body; the young of a corresponding European species is also free-swimming, like the young Edwardsia.

The coral polyps differ from the Actinoids in secreting in the mesoderm a limestone base, from which arise in the Zoantharian corals stony septa serving as a support to the animal; these septa are deposited or secreted in the chambers, so that in the coral polyp there are soft partitions alternating with the limestone ones, the latter formed at the base of the polyp, not completely filling the intermesenterial chambers.

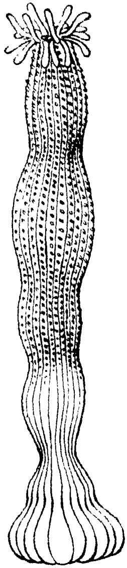


Fig. 52. — *Halcampa producta*. —After Verrill.

Order 1. *Zoantharia.*—We will now enumerate some of the leading forms of the first order of Anthozoa, the *Zoantharia*, to which the sea-anemones and most of the stony corals belong. The group is called by some recent authors *Hexacoralla*, the number of primary chambers and tentacles being six, the latter rounded, conical, or filiform. In the simple cup-shaped corals, as *Deltocyathus* and *Caryophyllia*, the coral forms a cup or *theca*, the lamellæ which arise from the base terminate in as many septa, the spaces between which are termed *loculi*. A central pillar or column formed by the union of the septa, or arising independently, is called the *columella,* while the small separate pillars between the columella and the septa are termed *paluli.* In the compound or tree-like corals, each young coral polyp forms a *calicle, theca,* or limestone support of its own, which unites with the other by calcification of the connecting substance of the common body. This intermediate layer is termed *cœnenchyma* (Huxley).

The simpler corals consist of but a single *calicle* containing one polyp, as in *Flabellum, Deltocyathus,* and *Caryophyllia.* They live free, fixed in the mud in deep water, and occur in water with a temperature of about 32° Fahr. *Flabellum angulare* Moseley has been dredged off Nova Scotia in 1250 fathoms.

Deltocyathus Agassizii, which is not uncommon in the Florida channel, at depths varying from sixty to three hundred and twenty-seven fathoms, has been dredged by us at the mouth of Massachusetts Bay, in one hundred and forty fathoms (temperature 39° to 42° Fahr.). An allied form is *Ulocyathus arcticus* Sars, said by Duncan to be the same as *Flabellum laciniatum* Edwards and Haime, a fossil of the late tertiary, dredged by us in one hundred and fifty fathoms, near St. George's Banks, Gulf of Maine.

In the family of which *Oculina,* the eye-coral, is a type, the polyp stock is compound, branched, increasing by lateral buds. *Lophohelia prolifera* Pallas (Fig. 53) occurs in the seas of Norway, and has likewise been found to occur on the banks off Nova Scotia and Newfoundland, while it lives in the Florida Straits, in from 195 to 315 fathoms.

In *Mæandrina,* or the brain-coral, *Favia, Astræa* and *Astrangia,* we have representatives of the important group *Astræacca,* in which the corallum is massive, more or less hemispherical, and the polyp-cells or calicles are distinctly lamello-radiate within, and generally so without. Budding is usually carried on by division of the disks, or by spontaneous fission. In *Mussa* the polyps are sometimes two inches in breadth, as large as ordinary Actiniæ. *Diploria cerebriformis* Edwards and Haime is a brain-coral which is common in the West Indies and at the Bermudas, sometimes growing to a diameter of three feet. The common large West Indian brain-coral is *Mæandrina labyrinthica.*

In *Astræa pallida* Dana, of the Feejee Islands, the polyps are pale, the disks bluish gray, and the tentacles whitish. The polyps of many corals are beautifully colored. Those of *Astrangia Danæ* Agassiz are white. In this coral, as observed by Dana, the polyps stand prominently above the calicles, as only their bases secrete coral. The tentacles have minute warty prominences, each full of lasso-cells.

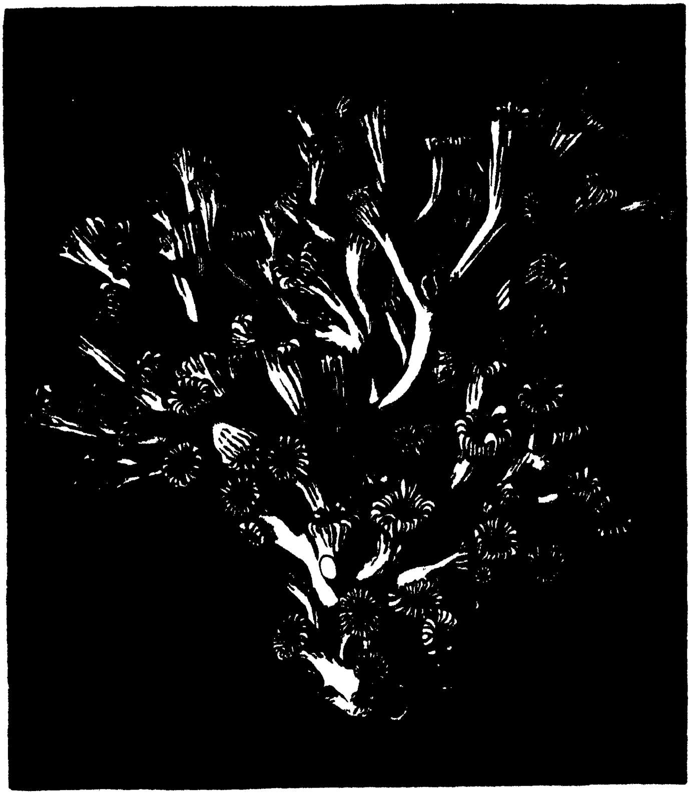


Fig. 53.—*Lophohelia prolifera.*—After Wyville-Thompson.

This coral ranges as far north as Nantucket and Buzzard's Bay. In the mushroom corals, *Fungia*, the large corallum is the secretion of a single polyp which may be a foot in length. Large branching corals abound on the reefs of Florida, the most abundant of which grows nearly two feet high and branches out like the horns of a deer. Such is *Madrepora cervicornis* Lamarck.

While agamogenesis or alternation of generations is rare among the *Actinozoa*, Semper has observed two species of *Fungia* which he considers to reproduce in this way. The corals "bud out from a branched stem, and then become detached and free, as is the habit of the genus." Moseley also describes a similar case of production of three or four generations in a Tahitan species of *Fungia*.

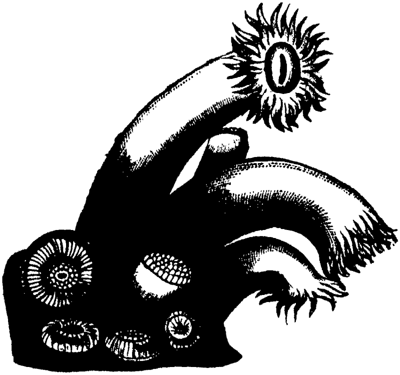


Fig. 54.—Coral polyp (*Astroides calycularis*) expanded.—From Tenney's Zoology.

As a good example of the mode of development of one of the suborder *Madreporaria*, we will, with Lacaze-Duthiers, study the development of *Astroides calycularis* Pallas. The period of reproduction takes place between the end of May and July, the young developing most actively at the end of June. Unlike Actinia, which is always hermaphroditic, this coral is rarely so, but the polyps of different branches belong to different sexes.

As in the other polyps, including Actinia, the eggs and spermatic bodies rupture the walls of their respective glands situated on the fleshy partitions. As in Actinia, Lacaze-Duthiers thinks the fecundation of the egg occurs before it leaves the ovary, when also the segmentation of the yolk must take place. Unlike the embryo Actinia, the ciliated young of the coral, after remaining in the digestive cavity for three or four weeks, make their way out into the world through the tentacles. The appearance of the young, when first observed, was like that in Fig. 55, *A*, being an oval, ciliated gastrula with a small mouth and a digestive cavity.

The gastrula changes into an actinoid polyp in from thirty to forty days in confinement, after exclusion from the parent, but in nature in a less time, and it probably does not usually leave the mother until ready to fix itself to the bottom.

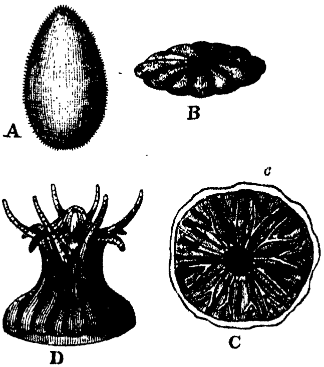


Fig. 55.—Development of a coral polyp, *Astroides calycularis*. *A*, ciliated gastrula; *B*, young polyp with 12 septa; *C*, *D*, young polyp farther advanced, with 12 tentacles; *c*, the corallum and limestone septa beginning to form.—After Lacaze-Duthiers.

Before the embryo becomes fixed and the tentacles arise, the lime destined to form the partitions begins to be deposited in the endoderm. Fig. 55, *C*, shows the twelve rudimentary septa. These after the young polyp or "actinula" has become stationary, finally enlarge and become joined to the external walls of the coral now in course of formation (Fig. 55, *C*, *c*), forming a groundwork or pedestal on which the actinula rests. *D* represents the young polyp resting on the limestone pedestal.

Lacaze-Duthiers found that the embryo polyp which had been swimming about in his jars for nearly a month, suddenly, within the space of three or four hours after a hot sirocco had been blowing for three days, assumed the form of small disks (Fig. 55, *B*), divided, as in the Actinia, into twelve small folds forming the bases of the partitions within.

The tentacles next arise, being the elongation of the chambers between the partitions, six larger and elevated, six smaller and depressed (Fig. 55, *D*). The definitive form of the coral polyp is now assumed, and in the Astroides it becomes a compound polypary.

There are but few facts regarding the rate of growth of corals. Pourtales states that a specimen of *Mæandrina labyrinthica,* measuring a foot in diameter and four inches thick in the most convex part, was taken from a block of concrete at Fort Jefferson, Tortugas, which had been in the water only twenty years. Major E. B. Hunt calculated that the average growth of a Mæandrina observed by him at Key West was half an inch a year. From the observations and specimens collected by Mr. J. A. Whipple, as stated by Verrill, a Madrepora found growing on the wreck of the Severn grew to a height of sixteen feet in sixty-four years, or at the rate of three inches a year.

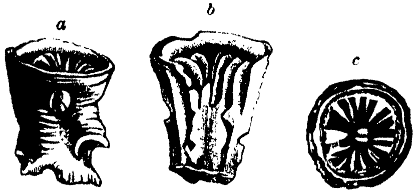


Fig. 56.—*a*, *Haplophyllia paradoxa* ; *b*. vertical section; *c*, calicle from above.—After Pourtales.

The group *Rugosa* of Milne-Edwards and Haime contains a large number of palæozoic corals, which are mainly characterized by having four primary septa, the number in most living corals being six ; and also by intracalicinal gemmation, which also occurs in a few Caryophyllids and Oculinids.

Pourtales has doubtfully referred to this group his *Haplophyllia paradoxa* (Fig. 56) which inhabits the Florida Straits at a depth of over three hundred fathoms. The nearest known fossil ally of this interesting coral is *Calophyllum profundum* Germ., which is fossil in the Dyas formation. Duncan describes *Guynia annulata,* another deep-sea coral, as a recent Rugose tetrameral coral. Moseley suggests from a study of *Heliopora,* together with *Cryptohelia* and other *Stylasteridæ,* that "the marked tetrameral arrangement of the septa in *Rugosa,* and the presence in many forms of tabulæ, are certainly characters not opposed to the alliance of these corals with the Alcyonarians," and gives other reasons of importance in favor of this view.

The group of *Antipathea*, represented by *Antipathes arborea* Dana, of the Feejee Islands, produce compound groups by budding, growing in the form of delicate shrubs. The polyps have usually six tentacles, though in *Gerardia* they have twenty-four.

Order 2. *Alcyonaria.*—To this group of polyps, which have eight serrated or feathered tentacles, belong the red coral of commerce, the sea-fans and sea-pens, in which there are no calcareous septa, and in which the corallum has, as in the sea-fans and sea-pens, a bony axis, while the fleshy portion (cœnosarc) represents the mesoderm and is filled with calcareous spicules.

In the genera *Haimea*, *Alcyonium*, *Tubipora*, etc., the polyps are encrusting, budding out in different ways, and adhere to foreign bodies by the cœnenchyma. *Haimea* is simple, consisting of but a single polyp. In *Alcyonium* the cœnenchym is much developed, soft, lobulated, and branching. Our common species is *A. carneum* Agassiz. In *Tubipora* the polyps are compound and secrete solid calcareous, bright red tubes, arranged side by side, like the pipes of an organ, and supported by horizontal plates.

In the common red coral (*Corallium rubrum*) of the Mediterranean Sea, the solid, unjointed coral-stock consists of a crystalline basal mass, with calcareous spicules solidly united. The bright red coral is worked into various ornaments. The coral fishery is pursued on the coasts of Algiers and Tunis, where assemble in the winter and spring from two hundred to three hundred vessels. The coral-fishermen, with large rude nets, break off the coral from the submerged rocks. About half a million dollars' worth of coral is annually gathered.

Heliopora, now proved by Mr. H. N. Moseley to be an Alcyonarian instead of an Actinoid polyp, differs from *Corallium* and *Tubipora* "in that the hard tissue of its corallum shows no signs of being composed of fused spicules." This genus, together with *Polytremacis* and the

Silurian *Heliolites*, form, according to Moseley, a new family of Alcyonarians in which the corallum consists of an abundant tubular cœnenchym, with calicles having an irregular number of pseudo-septa, which do not, however, correspond with the membranous mesenteries. The polyps are completely retractile, with the tentacles when retracted introverted. The mouths of the sacs lining the cœnenchymal tubes are closed with a layer of soft tissue, but communicate with one another and with the calicular cavities by a system of transverse canals (Moseley). *Heliopora cærulea* grows on coral reefs at the Philippine Islands and at Singapore.

In the family of sea-fans (*Gorgonidæ*) the coral-stock is horny or calcareous, branching tree-like, or forming a flat network. The short calicles of the single retractile polyps stand perpendicularly to the axis, communicating by longitudinal vessels and branching canals. *Gorgonia* (*Rhipigorgia*) *flabellum* Linn. is red or yellow and abundant on the Florida reefs. In the Arctic seas and the deeper, colder waters of the Newfoundland Banks and St. George's Banks, *Primnoa reseda* (Pallas) and *Paragorgia arborea* (Linn.) grow; the latter being of great size, the stem as thick through as one's wrist, and the whole corallum over five feet in height.

In the family of sea-pens (*Pennatulidæ*) the polyp-stock is free, growing in the sand or mud, usually with a bony axis supporting the polyps, and capable of moving at the base. In *Pennatula*, or the sea-pen, there are secondary branches in which the polyps are situated; this polyp is phosphorescent; one species (*P. aculeata* Danielssen) lives in deep water. An Arctic form, *Umbellularia groenlandica*, is a gigantic form, growing about four feet high, in from three hundred to two thousand fathoms. The species of *Renilla* are kidney-shaped, with the polyps placed on one side. *Renilla reniformis* Cuvier is a rich purple species, occurring in the sand at Charleston, S. C. According to Agassiz, this animal is remarkably phosphorescent, emitting "a golden green light of a most wonderful softness."

While coral reefs are in part composed of Alcyonarians, Polyzoa, and certain plants called Nullipores, the *Madreporaria* in the main are the true reef-builders. They are confined to waters in which through the coldest winter month the temperature of the water does not fall below 68° F., though usually the waters are much warmer than this, the mean annual temperature being about 73½° F. in the North Pacific and 70° F. in the South. Coral reefs are abundant in the West Indies, but still more so in the Central Pacific, where there are a much greater number of species of corals (Dana). Along the Brazilian coast, as far south as Cape Frio, are coral reefs (Hartt). In depth living coral-reef-builders do not extend more than fifteen or twenty fathoms below the surface.

Coral reefs are divided by Dana into outer or barrier reefs (Fig. 57) and inner reefs. The barrier reefs are formed from the growth of corals exposed to the open seas, while the inner or fringing reefs (Fig. 57) are formed in quiet water between a barrier reef and the island. As coral reefs are usually built upon islands which are slowly sinking, barrier reefs are simply ancient fringing reefs formed when the island stood higher above the sea, hence they are built up as rapidly as the land sinks, and thus the top of the reef keeps at the level of

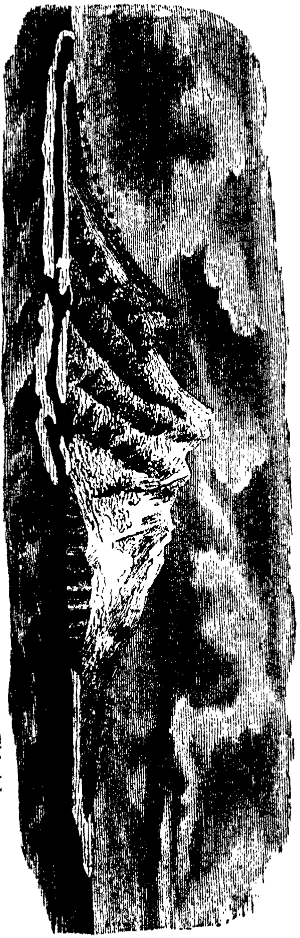


Fig. 57.—B rrier and fringi reef.—From Brehm's Thierleben.

the sea. The reefs are often of great thickness, for, as Dana says, "could we raise one of these coral-bound islands from the waves, we should find that the reefs stand upon

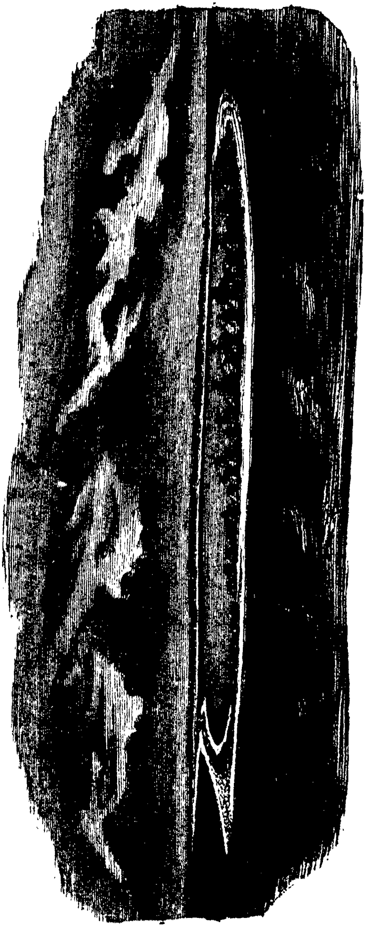


Fig. 58.—Coral island or atoll.—From Brehm's Thierleben.

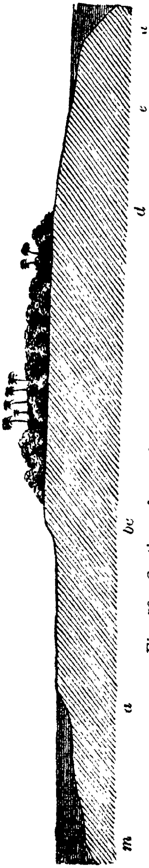


Fig. 59.—Section of a reef.—From Brehm's Thierleben.

the submarine slopes, like massy structures of artificial masonry; some forming a broad flat platform or shelf ranging around the land, and others encircling it like vast ramparts, perhaps a hundred miles or more in circuit." Darwin has estimated that some reefs in the Pacific Ocean are at least 2000 feet in thickness.

Thus far we have spoken of reefs surrounding mountainous islands; coral islands or *atolls* (Fig. 58) resemble such reefs, except that they surround a lake or lagoon instead of a high island, the coral island itself being seldom more than ten or twelve feet above the sea, and usually supporting a growth of cocoanut trees, while the sea may be of great depth very near the outer edge of the atoll, which "usually seems to stand as if stilted up in a fathomless sea" (Dana). These reefs and atolls are formed and raised above the sea by the action of the winds and waves, in breaking up the living corals, comminuting it and forming with the débris of shells and other limestone-secreting animals and plants, banks or deposits of coral mixed with a chalky limestone, as the base of the reef. When it rises above the waves, cocoanuts and other seeds are caught and washed up on the top, and gradually the island becomes large enough to support a few human beings. The Bermudas are the remnants of a single atoll, and are situated farther from the equator than any other reefs. Most barrier reefs and coral islands or atolls are formed in an area of subsidence, where the bottom of the ocean is gradually sinking; this accounts for the peculiar form and great thickness of many reefs. On the other hand, the coral reefs of the West Indies are, generally speaking, in an area of elevation.

A section of a coral reef is shown by Fig. 59: *n* is the point where the shore slopes rapidly down within the lagoon (which lies to the right), and *m* is where the reef suddenly descends toward the open ocean. Between *b c* and *d e* lies the higher part of the reef. The shore toward the lagoon slopes away regularly from *d* to *n*; while toward the open ocean there is a broad horizontal terrace (*a* to *b c*) which becomes uncovered at low water.

The theory of the formation of barrier reefs is shown by the diagram, Fig. 60. The island, for example, the volcanic island Coro, which is slowly sinking, at the ancient sea-level I is surrounded by a fringing reef *f f*, a small rock-terrace at the former level of the sea. Where the island has sunk to the level of the water-line II, the reef appears at the surface as at $b' f'$, $b f$. There is now a fringing and a barrier reef, with a narrow canal between them; b' is a section of the barrier reef, e' of the canal or lagoon, and f' of the fringing reef. After a farther submergence to the sea-level III, the canal e'' becomes much wider. On one side $(f f)$ the reef is present, on the other side it has disappeared, owing to the agency of ocean-currents. Finally, at the water-level IV, there are two small islands surrounded by a wide lagoon, with two reef-islets i''', i''', resting upon two submarine peaks. The coral reef has now grown to great dimensions, and covered almost the entire original island, and though the reef-building coral polyps cannot live below a point fifteen or twenty fathoms below the surface, yet owing to the slow sinking of the island, they build up the reef as rapidly as the former subsides, and in this way after many centuries a coral reef sometimes two thousand feet thick may be built up in mid-ocean.

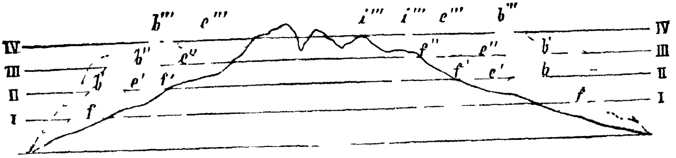


Fig. 60—Schematic section of an island with reefs

Coral reefs are mainly confined to the Western and Central Pacific and the Indian Oceans, and to the Caribbean Sea. None occur on the west coast of North America or of Africa, and only limited patches on the eastern coast of South America. There were palæozoic reefs, such as the fossil coral reef extending across the Ohio River at Louisville.

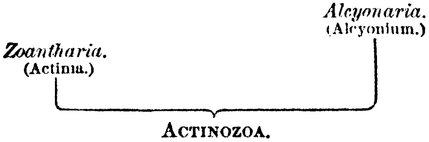
CLASS II.—THE ACTINOZOA.

Cœlenterates with a digestive sac partially free from the body-cavity opening into it below and held in place by six or eight mesenteries radiating from the digestive cavity and dividing the perivisceral space into chambers. Mouth surrounded with a circle of tentacles, which are hollow, communicating directly with the perivisceral chambers. A slightly marked bilateral symmetry. To the edges of the mesenteries (usually the free ones) are attached the reproductive glands, both male and female, or of one sex alone; also the craspeda, or mesenterial filaments, which contain a large number of lasso-cells. Body either entirely fleshy, or secreting a calcareous or horny coral-stock, and when the species is social connected by a cœnenchyme. In some forms (sea-pens) the entire colony capable of limited locomotion. No well-marked nervous system, but a plexus of fusiform ganglionic cells connected by nerve-fibres in the base of Actinians. Reproduction by self division, gemmation, or by ova, the sexes being separate or united in the same individual; the young undergoing a morula and gastrula condition, and then becoming fixed.

Order 1. *Zoantharia.*—Mesenteries and tentacles usually six or in multiples of six, corallum with calcareous septa. Mesenterial filaments abundantly developed (Astræa, Madrepora, Actinia).

Order 2. *Alcyonaria.*—Mesenteries and tentacles always eight in number. Coral-stock without true septa. Mesenterial filaments not usually numerous Corallum usually horny, and the whole colony in the Pennatulacea capable of locomotion (Alcyonium, Gorgonia, Pennatula, Renilla).

VIEW OF THE CLASSIFICATION OF THE ACTINOZOA.



Laboratory Work.—Verrill has preserved Actiniæ completely expanded by slowly adding a saturated solution of picric acid to a small quantity of sea-water in which they had expanded. When dead they should be transferred to a pure saturated solution of the acid, and allowed to remain for from one to three hours, according to size, etc. They should then be placed in alcohol, which should after a day or two be renewed. Thus hardened they can be cut into sections. Corals can be studied by grinding or sawing sections, and, if desirable, treated as in the case of the corallum of the Millepores.

CLASS III.—CTENOPHORA (*Comb-bearers*).

General Characters of Ctenophores.—These beautiful animals derive their name *Ctenophora*, or "comb-bearers," from the vertical rows of comb-like paddles (ctenophores) situated on meridional bands of muscles which serve as locomotive organs, the body not contracting and dilating as in the true jelly-fishes. In their organization they are more complicated than the *Actinozoa*, as they have a true digestive cavity passing through the body-cavity, with two posterior outlets (it will be remembered that *Cerianthus* has one at the end of the body). From this alimentary canal are sent off chymiferous or water-vascular canals (Fig. 61) which correspond in their mode of origin with the water-tubes of the Echinoderms. As regards the rows of paddles, each vertical row consists of a great number of isolated, transverse, comb-like fringes placed one above the other, and movable, either isolately or in regular succession or simultaneously (Agassiz). As these rows of paddles are connected for their whole length with a chymiferous tube, they probably aid in respiration. These animals also stand much higher in the scale of life than the other Cœlenterates by being more truly bilateral, the radial symmetry so marked in the *Actinia* or in the jelly-fish being in these animals less apparent, as the parts are developed on opposite sides of a median plane. The nervous system, as originally described by Grant, consists of a ganglion situated at the aboral end (end opposite to the mouth) of the *Pleurobrachia*, from which, among other nerves, eight principal ones are distributed to the eight rows of paddles. A nerve also proceeds to the so-called otolitic sac (lithocyst) seated upon the ganglion. Eimer has lately shown that the nervous system of the

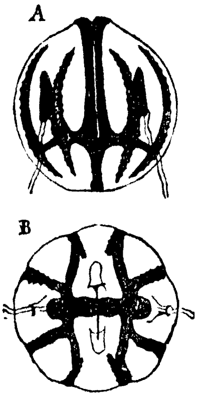


Fig. 61.—View of the gastro-vascular canals of a *Pleurobrachia*, from which the two retractile arms have been removed. *A*, from one side, the mouth-opening above; *B*, seen from the mouth-end.—After Gegenbaur.

Ctenophora, as, for example, that of *Beroë*, agrees in general with that of the jelly-fishes, with the difference that in the Ctenophores the nerve-centres are not situated on the edge, but at the pole of the body opposite the mouth. On the other hand, the nervous system is not radiated as in the jelly-fishes or as in the Echinoderms.

Our commonest example of this class is the *Pleurobrachia rhododacyla* Agassiz. It is a beautiful animated ball of transparent jelly moving through the water by means of eight rows of minute paddles, throwing out from a sac on each side of the body two long ciliated tentacles. It is abundant in autumn ; sometimes thousands may be seen stranded on the shore at low water.

That the Ctenophores have affinities to the sea-anemones (*Actinozoa*) is seen in the form and relations of the digestive tract, though it differs in hanging free, not being held in place by radiating mesenteries, and in this respect they approach the Echinoderms. From their possessing a distinct digestive tract, the Ctenophores need not be confounded with the jelly-fishes (*Hydrozoa*). On the other hand, they present some advance over the *Actinozoa*, and in some respects connect the *Hydrozoa* and *Actinozoa* with the Echinoderms. For example, the water-vascular system arises in the Ctenophores as outgrowths from the digestive sac, as they do in the young star-fish and sea-urchins. This indicates that in the mode of development of both the digestive tract and the water-vascular system the Ctenophores are allied to the Echinoderms rather than to the *Hydrozoa*, in which the water-vascular tubes arise as simple hollows in the body-mass. Moreover, they are less radiated than in the *Hydrozoa* or Echinoderms.

In *Bolina alata* Agassiz the body is plainly bilateral and the water-vascular tubes are very distinct. In *Idyia roseola* Agassiz the mouth is large, the stomach wide, and the body is of an intense roseate hue. This beautiful species after death, late in summer, is very phosphorescent ; all Ctenophores, however, even their eggs and embryos, are phosphorescent. In the Ctenophores the ovaries and spermaries occur in the same individual and form blind sacs attached to the water-vascular tubes, and are developed locally, as in *Cestum*, or along the whole length of the tubes, the sexually-different glands being placed in *Beroë* and allies on opposite sides of the tube.

When ripe the eggs pass into the perivisceral space, and finally pass out through the openings of the body. The eggs of *Pleurobrachia* escape singly; in *Bolina* they are laid in strings, while those of Idyia are deposited in a thick slimy mass. They spawn late in the summer and in the autumn. The young develop in the autumn, becoming nearly mature in the following spring. Development is direct, the young hatching nearly with the form of the adult, there being no metamorphosis.

The species are widely distributed, a number being common to both sides of the Atlantic, and the same species, apparently, of *Pleurobrachia* and *Idyia* occur on the east and west coast of North America. The most widely distributed forms are the Beroids. While the genus *Mertensia* is entirely arctic, the larger number of species are either tropical or subtropical. The classification of the group is shown in the following summary.

CLASS III.—CTENOPHORA.

Spherical or oval, somewhat bilateral, scarcely radiated animals, with jelly-like, transparent bodies. The digestive tract opens at the posterior end into the perivisceral cavity; from the canal pass off eight water-vascular tubes, which are in close relation with eight vertical meridional series of comb-like locomotive organs. Usually a pair of tentacles, which may become withdrawn into sacs, and are provided with thickset lasso-cells on the tentacular fringes. Nervous system consisting of an aboral ganglion, sending off eight nervous filaments to each of the eight rows of paddles. The sexual glands seated in the same individual. No metamorphosis, the young when hatched resembling the adult.

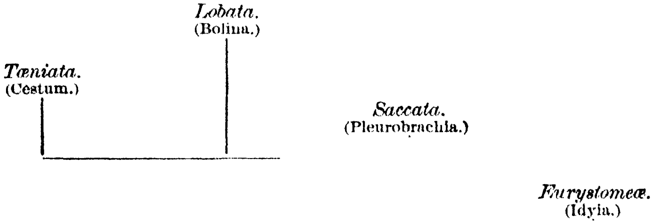
Order 1. *Eurystomeæ.*—Body oval, with a large mouth and capacious stomach. The water-vascular tubes connected with the ctenophores, and forming numerous ramifications, communicating by means of a circular canal near the mouth (Beroë, Idyia).

Order 2. *Saccatæ.*—Body more or less spherical, with two long tentacles capable of being wholly retracted in a sac (Pleurobrachia).

Order 3. *Tæniata.*—Body ribbon-like, being very much compressed in the direction of the lateral diameter (Cestum).

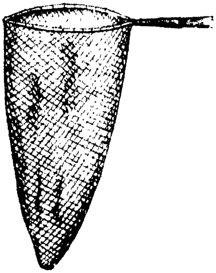
Order 4. *Lobatæ.*—Body lateral, compressed, bilobed (Bolina).

VIEW OF THE CLASSIFICATION OF THE CTENOPHORA.



CTENOPHORA.

Laboratory Work.—The Ctenophoræ should be studied while alive. They may be collected with a drag or tow-net from a boat when the surface of the ocean is calm. For studying the fine anatomy and tissues they should be treated by the same methods as the smaller jelly-fishes.



CHAPTER IV.

BRANCH IV.—ECHINODERMATA (STAR-FISH, SEA-URCHINS, SEA-CUCUMBERS, ETC.)

General Characters of Echinoderms.—We now come to animals of much more complicated structure than any of the foregoing branches, and in which the radiated arrangement of the parts of the body is in most cases as marked as the jointed or ringed structure of worms or insects ; for not only are the body-walls of the star-fish or sea-urchin, or even many of the Holothurians (though less plainly), divided into five wedge-shaped portions (*spheromeres*), or produced into five arms as in the common star-fish or five-finger, but the nervous system, the reproductive organs, the blood and water-vascular systems, and the locomotive appendages of the latter, are usually arranged in accordance with the externally radiated form of the body. Still these animals are in many cases, as in the higher sea-urchins, plainly bilateral, while in the larval forms of all Echinoderms whose development is known the young are not radiated, but more or less bilateral, as in the larvæ of worms and mollusks. The most trenchant character, however, separating the Echinoderms from the Cœlenterates, and allying them to the worms, is the genuine tube-like digestive canal which lies free in the body-cavity (perivisceral cavity), and may be several or many times the length of the body.

The student can gain a correct idea of the general structure of the Echinoderms from a careful examination of the common star-fish (*Asterias vulgaris* Stimpson), which is the most common and accessible Echinoderm to be found on the New England shores. After placing a star-fish in some sea-water and noticing its motions, the thrusting out of the ambulacral feet or suckers by which it pulls or warps its clumsy body over the mussel-beds, or rocks, or weeds, the arms being capable of slightly bending; after observing the red eye-spot at the end of each arm or ray, and the movements of the numerous spines which are attached to the separate plates forming the calcareous framework of the body-walls, and examining the movements of certain modified spines called *pedicellariæ,* which are pincer-like bodies situated among the spines, the student will be ready to study the external and internal anatomy.

First, as to the calcareous framework of the star-fish. In order to study this, a transverse section should be made through an arm, and a vertical one through the body and along the middle of a single arm, and finally the animal should be divided into two halves, an upper and lower. It will then be seen that the calcareous framework or so-called skeleton consists of a great number of limestone plates or pieces attached by a tough membrane and covered by the skin. Between the plates are spaces by which the water enters the body-cavity through the skin. These plates are arranged so as to give the greatest strength and lightness to the body. There is also to be seen an oral (actinal) side on which the mouth is situated, and an aboral (abactinal) side, the respective limits of which areas vary greatly in the different groups of Echinoderms. Each arm or ray is deeply channelled by the ambulacral furrow containing four rows of suckers or "ambulacral feet," which are tentacle-like protrusions of the skin growing out through orifices in the ambulacral plates, and are a continuation of the water-sacs or "ampullæ" within. The madreporic plate is a flattened hemispherical body situated on the disk between two of the arms. It is perforated by canals.

We are now ready to examine the internal organs and to study their relations to one another and to the body-walls. The nervous system may be seen without dissection. By closely examining the mouth a pentagonal ring is seen surrounding it, each angle slightly enlarging* and sending off a nervous cord to the eye at the end of the ray. It may be discovered by pressing apart the ambulacral feet along the median line of each arm. Fine nerves are sent off to each sucker, passing through the opening between the calcareous plates and extending to each ampulla, thus controlling the movements of the ambulacral feet.

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* Owfsiannikoff states that the nervous ring is a flat band, containing no swellings or ganglia, and not differing in structure from the ambulacral nerves, which latter possess nerve-cells as well as fibres.

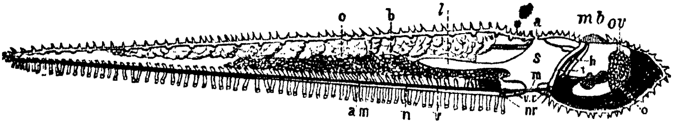

Fig. 62.—Longitudinal section through the body and one arm of *Asterias vulgaris*. *m*, mouth; *s*, stomach; *l*, lobe of stomach extending into the arm; *a*, anus; *nr*, nervous ring; *n*, radial nerve; *vr*, water-vascular ring, sending a radial vessel (*v*) into the arm; *mp*, madreporic plate; *t*, stone canal; *h*, hæmal canal; *ov*, oviduct; *o*, ovary; *am*, ampullæ, the ambulacral feet projecting below; *b*, cœca or liver.—Drawn by A. F. Gray, under author's direction.

The mouth (Fig. 62, *m*) is capacious, opening by a short œsophagus into a capacious stomach (Fig. 62, *s*) with thin distensible walls, and sending a long lobe or sac (Fig. 62, *l*) into the base of each arm; each sac is bound down by two retractor muscles attached to the median ridge lying between the two rows of water-sacs (ampullæ, see also Fig. 63).

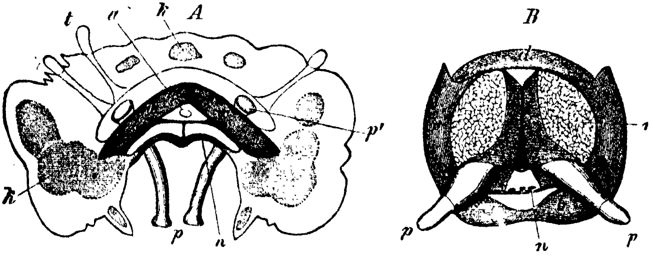

Fig. 63.—Diagram of the cross-section of an arm. *A*, of *Asterias rubens*; *B*, of *Ophiura texturata*; *p*, ambulacral feet; *p'*, ampullæ; *t*, dermal tentacles; *n*, nervous cords; *w*, ambulacral plates; *m*, muscles; *a*, ambulacral vein; *b*, ventral plate; *c*, lateral plates; *d*, dorsal plate; *k*, calcified portion of the integument.—After W. Lange from Gegenbaur.

The stomach ends in a short intestine, the limits between the two not distinctly seen. The intestine suddenly contracts and ends in a minute rectum situated in an angle between two of five fleshy ridges radiating from the centre of the aboral disk. The anus (Fig. 62, *a*) is minute and difficult to detect, being situated between the short spines, and is evidently not used in the expulsion of fæcal matter unless the urinary secretions, if there be such, pass out of it. It would seem as if the opening were rudimentary and that the star-fish had descended from Echinoderms like the Crinoids, in which there is a well-marked external terminal opening of the digestive tract. Appended to the intestine are the "cœca" or "liver" (Fig. 62, *b*), consisting of two long, tree-like masses formed of dense branches of from four to six pear-shaped follicles, connecting by a short duct with the main stem. The two main ducts unite to form a short common opening into the intestine. The cœca are usually dark, livid green, and secrete a bitter digestive fluid, representing probably the bile of the higher animals.

The star-fish is bisexual, but the reproductive glands are much alike, the sexes only being distinguishable by a microscopic examination of the glands. The ovaries (Fig. 62, *o*) are long racemose bodies lying along each side of the interior of the arms, and the eggs are said to pass out by a short narrow oviduct (*ov*) through an opening between two plates on each side of the base of the arms, the opening being small and difficult to detect.

The water-vascular system consists of the madreporic body, the "stone-canal" (Fig. 62, *t*), the ring or circumoral canal (*vr*), and the radial vessels (*v*) ending in the water-sacs (*am*) and ambulacral feet. The stone-canal begins at the outer and under side of the sieve-like madreporic body, passing directly forward and downward in a sinuous course to the under side of the circumoral plates. The madreporic body (*mb*) is externally seen to be perforated by linear apertures radiating and subdividing toward the periphery. The sea-water in part enters the body-cavity through the fissures in the madreporic body, while most of it enters the stone-canal, which is a slender tube scarcely one fourth the diameter of the entire madreporic body. The water entering the stone-canal (Fig. 62, *t*) passes directly into the water-vascular ring (Fig. 62) and then into the ten Polian vesicles and the five radial canals, whence it is conveyed to each water-sac or ampulla (Fig. 62, *am*). These pear-shaped water-sacs, when contracted, are supposed to press the water into the long slender suckers or ambulacral feet, which are distended, elongated, and by a sucker-like arrangement at the end of the prehensile foot act in conjunction with the others to warp or pull the star-fish along. Besides locomotion the ambulacral feet serve for respiration and perception (Simroth). Hoffman shows that the feet of the sea-urchins can be projected or thrust out without the aid of the ampullæ.

It will thus be seen that the water-vascular system in the star-fish is in its functions partly respiratory and partly locomotive, while it is in connection with the vascular system, and thus partly aids in circulating the blood and chyle.

Of the true vascular or blood system the student can ordinarily only discover one portion, the so-called "heart" or "pulsating vessel," which we may call the hæmal canal (Fig. 62 *h*), and which runs parallel to the stone-canal from the madreporic body to near the ring-canal.* It is nearly as large as the stone-canal, slightly sinuous, muscular, and with the latter is surrounded by a loose investing membrane like a pericardium. Some observers deny the existence of a vascular (sometimes called "pseudohæmal") system, but it has been recently studied by Hoffman and subsequently by Teuscher, who maintains that in all Echinoderms there are two systems of blood-vessels, which belong, one to the viscera and the other to the nervous system, forming an oral or nervous ring and an anal ring. The two rings are in direct communication in the star-fishes, Ophiurans and sea-urchins, but not in the Holothurians. The radial nerves are accompanied by a vessel which subdivides and distributes branches to the ambulacral feet in star-fishes, Echini, and Holothurians. Teuscher considers that the "heart" found in the star-fishes and Echini connecting the œsophageal (or nerve-ring) and anal ring, is neither a gland nor a pulsating vessel, as different authors have supposed, but perhaps only a relict of an earlier period of development. In the Ophiurans the oral canal opens directly into the body-cavity; in *Echinothrix* directly connects with the outer world by means of the interradial canals. Finally, he regards the nervous vessel as homologous with the ventral vessel of the worms.

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* Simroth states that in Ophiurans (Ophiactis) the stone-canal opens in common with the "heart" into the madreporic plate.

Having made ourselves acquainted with the general structure of the Echinoderms as exemplified in the star-fish, we are prepared to study the modifications of the Echinoderm plan in the different classes.

CLASS I.—CRINOIDEA (*Stone-lilies, Encrinites, etc.*)

Order 1. *Brachiata.*—The living representatives of those Crinoids which lived in palæozoic and early mesozoic times are few in number, and for the most part live in deep water, or, as in the case of *Rhizocrinus* and its living allies, at great depths. They are like *Limulus* and *Nebalia*, remnants of an ancient fauna. There are but eight genera known—viz., *Holopus*, *Rhizocrinus*, *Bathycrinus*, *Hyocrinus*, *Pentacrinus*, *Comaster*, *Actinometra*, and *Antedon* (*Comatula*). Of the first five genera the species are attached by a stalk to the sea-bottom, while the last three genera are in their young state stalked, but finally become detached. The body or calyx divides into arms bearing *pinnulæ* or sub-branches.

The *Pentacrinus* lives attached to rocks from twenty to thirty fathoms below low-water mark in the West Indies. The stem is about a foot long, the joints pentagonal, sending off at intervals whorls of unbranched cirri. "No distinct basal piece is known, but the calyx appears to begin with the first five radialia" (Huxley). *Pentacrinus caput-medusæ* Müller (Fig. 64) and *P. Mülleri* Oersted are West Indian species. *P. Wyville-Thompsoni* Jeffreys was dredged in deep water on the coast of Portugal. In the fossil *P. subangularis* the stalk was more than fifty feet long. *Bathycrinus gracilis* Wyville-Thompson is closely allied to *Rhizocrinus*, and was dredged in the Bay of Biscay t the depth of 2435 fathoms. *B. Aldrichianus* occurred in 1850 fathoms, latitude 1° 47′ N., longitude 24° 26′ W., off the coast of Brazil. With it and also near the Crozet Islands occurred the interesting *Hyocrinus Bethellianus* Wyville-Thompson, which bears in some points resemblance to the palæozoic genus, *Platycrinus*.

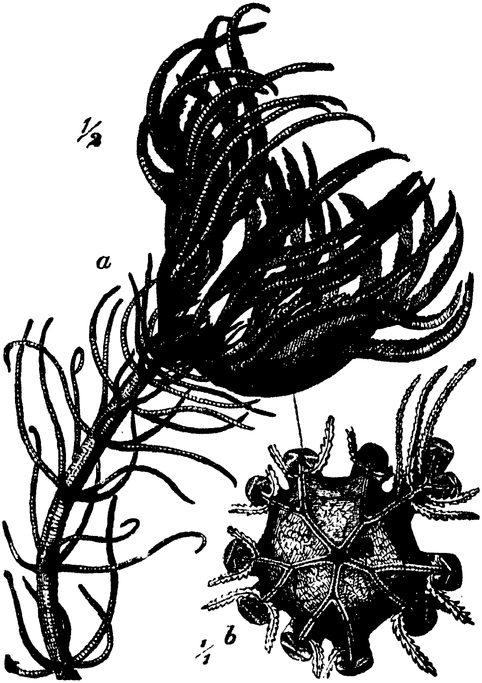

Fig. 64.—*a*, *Pentacrinus caput-medusæ*, half natural size; *b*, calyx-disk seen from above, natural size.—From Brehm's Thierleben.

The most widely distributed species is the *Rhizocrinus lofotensis* of Sars (Fig. 65), which is closely related to the *Bourguetticrinus* of the chalk formation, and forms the transitional type connecting the *Apiocrinidæ* with the free-moving, unstalked *Antedon*. It occurs at the depth of from one hundred to one thousand fathoms in the North Atlantic and Floridan seas, and is a characteristic member of the abyssal fauna. This crinoid consists of a jointed stalk, a cup-shaped body (*calyx*), from the edge of which from five to seven (the number varies) arms (*brachia*) radiate, which subdivide into a double alternate series of *pinnulæ*. The mouth is situated in the centre, while the anus is situated on a conical projection on one side of the oral disk, between the bases of two of the arms. *R. Rawsoni* Pourtales occurs in from eighty to one hundred and twenty fathoms at Barbadoes.

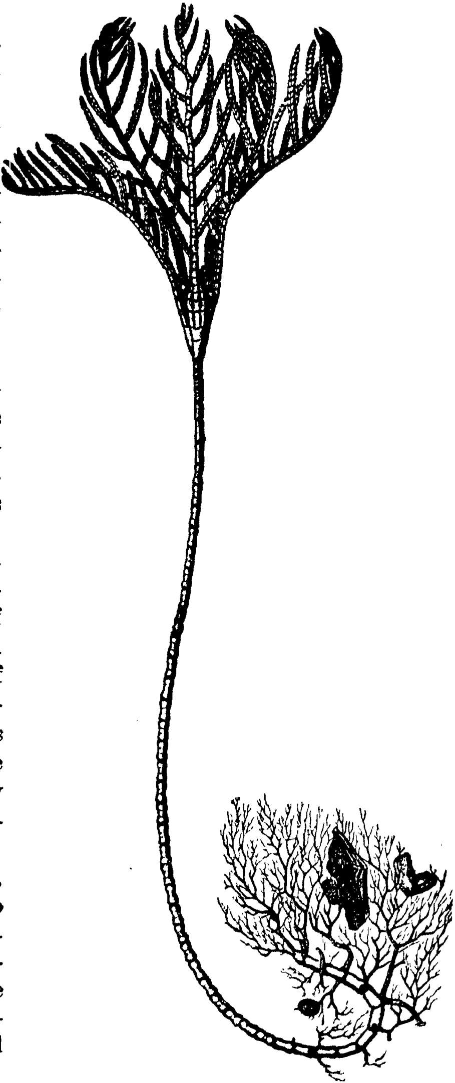

Fig. 65.—*Rhizocrinus lofotensis* Sars, twice natural

In *Holopus*, a short, stout form with no true stalk, but attached by a broad encrusting base, there are ten arms originating from five axial joints. "When contracted the arms are rolled in a spiral and press laterally against one another so as to enclose a hermetically closed cavity." The pinnules are formed of broad flat joints, and are "rolled spirally toward the ambulacral channel of the arms when contracted" (Pourtales). The only species yet known is *H. Rangii* D'Orbigny, from Barbadoes.

In *Antedon* (*Comatula*) the body is at first stalked, but afterward drops off, when it represents the calyx and arms of the ordinary Crinoids. It thus passes through a Rhizocrinus condition, showing that it is a higher, more recent form. The mouth opens into a short, broad œsophagus, and a wide stomach which makes a turn and a half, ending in the anal cone placed between the base of two of the arms. Within the five triangular plates is a circle of tentacles. From the space between each pair of oral plates the ambulacral grooves radiate to the arms and their branches. H. Ludwig maintains that *Antedon* possesses a true water-vascular system formed on the typical Echinoderm plan; there being a ring-canal, with radial vessels arising from it. The tentacles of the perisome are connected with the ring-canal, and the tentacles of the arms and pinnulæ are connected with the radial vessel. Ludwig has also discovered in *Antedon* a system of blood-vessels ("pseudo-hæmal" system) consisting of an oral ring-canal and five vessels radiating from it, which send branches to the tentacles, as in *Asterias*. He also detected a "dorsal organ," which he, contrary to Perrier and P. H. Carpenter, considers to be the central organ of the whole system of blood-vessels. Both Ludwig and Carpenter, however, regard it as homologous with the so-called "heart" or hæmal canal of Echini and Asterias.

The nervous system consists of an oral ring with branches extending into the arms.

The body-cavity extends into the arms, and the ovaries for the most part lie in the cavity of the arms, as in *Asterias*.

The internal anatomy of *Rhizocrinus* has been investigated by Ludwig, who finds that it agrees very closely with that of Antedon. The water-vascular system, nervous system, alimentary canal and its appendages, have the same relations as in the unstalked Crinoids (*Antedon* and *Actinometra*), only they are on a simpler plan, there being a close similarity between *Rhizocrinus* and the pentacrinoid stage of *Antedon.*

The ovaries of Antedon open externally on the pinnules of the arms, while there is no special opening for the products of the male glands, and Thompson thinks that the spermatic particles are "discharged by the thinning away and dehiscence of the integument." The ripe eggs hang for three or four days from the opening like a bunch of grapes, and it is during this time that they are fertilized. The following account is taken (sometimes word for word) from Wyville-Thompson's researches on *Antedon rosaceus* (Fig. 67) of the European seas. In the first stage the egg undergoes total segmentation (Fig. 66). *A* represents the egg with four nucleated cells, an early phase of the mulberry or morula stage. After the process of segmentation of the yolk is finished, the cells become fused together into a mass of indifferent protoplasm, with no trace of organization, but with a few fat cells in the centre. This protoplasmic layer becomes converted into an oval embryo, whose surface is uniformly ciliated. The mouth is formed with the large cilia around it before the embryo leaves the

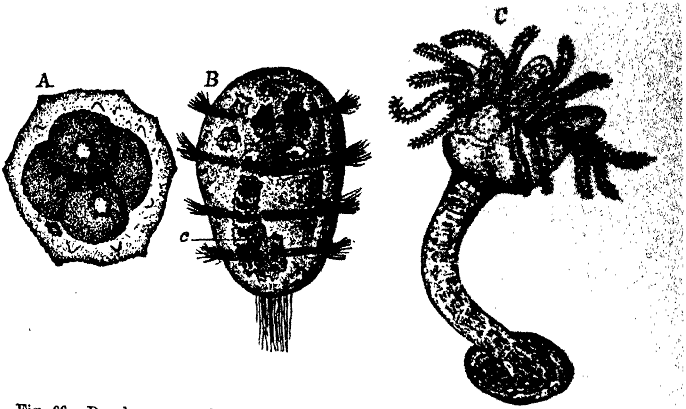

Fig. 66.—Development of a Crinoid (*Antedon*). *A*, morula; *B*, fr
oid.—After Wyville-Thompson.

egg. When hatched, the larva is long, oval, and girded with four zones of cilia, with a tuft of cilia at the end, a mouth and anal-opening, and is about eight millimetres long. The body-cavity is formed by an inversion of the primitive layer which seems to correspond to the ectoderm.

Within a few hours or sometimes days, there are indications of the calcareous areolated plates forming the cup of the future crinoid. Soon others appear forming a sort of trellis-work of plates, and gradually build up the stalk, and lastly appears the cribriform basal plate. Fig. 66, *B*, *c*, represents the young crinoid in the middle of the larva, whose body is somewhat compressed under the covering-glass.

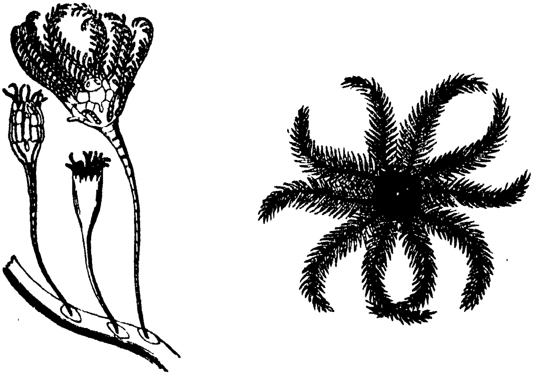

Fig. 67.—*Antedon*, stalked and free.—From Macallister.

Next appears a hollow sheath of parallel calcareous rods, bound, as it were, in the centre by the calcareous plates. This stalk (*B*, *c*) arises on one side of the digestive cavity of the larva, and there is no connection between the body-cavity of the larva and that of the embryo crinoid.

Two or three days after the appearance of the plates of the crinoid, the larva begins to change its form. The mouth and digestive cavity disappear, not being converted into those of the crinoid. The larva sinks to the bottom, there resting on a sea-weed or stone, to which it finally adheres. The Pentacrinus form is embedded in the larval body

Afterward five or more, usually fifteen tentacles, grow out, and the young Antedon appears, as in Fig. 66, *C.* The walls of the stomach then separate from the body-walls. The animal now begins to represent the primary stalked stage of the Crinoids, that which is the permanent stage in *Rhizocrinus*, *Pentacrinus*, and their fossil allies. After living attached for a while (Fig. 67), it becomes free (see right-hand figure) and moves about over the sea-bottom.

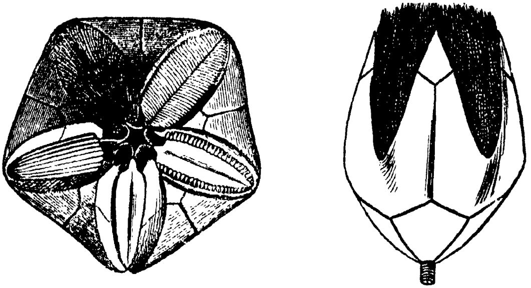

Fig. 68.—A Blastoid, *Pentremites*, seen from the side and from above.—After Lütken.

There are two species of Antedon on the New England coast, one (*A. Sarsii*) inhabiting deep water in about one hundred fathoms, and the other (*A. Eschrichtii* Müller) shallower water (twenty-five fathoms) in the Gulf of Maine.

Order 2. *Blastoidea.*—No forms have been discovered later than the Carboniferous period. The group began its existence as species of *Pentremites* (Fig. 68) in the Upper Silurian, and culminated in the Carboniferous age. It connects the Crinoids with the Cystideans ; the species have no arms, are supported on a short, jointed stalk, and the oral plates, when closed, as they are in a fossil state, make the calyx look like a flower-bud. There is a mouth and eccentric anal outlet and five radiating grooves, along each side of which are attached a row of pinnules. Besides *Pentremites* are the typical genera *Elæacrinus* and *Eleatherocrinus.*

Order 3. *Cystideæ.*—This group is likewise extinct. In the fossil *Pseudocrinus* there is a short-jointed stalk, while in *Caryocystites* (Fig. 69) there is no stalk and no arms, the body being angulo-spherical, composed of solid plates. The Cystideans (Figs. 69 to 71) originated in the Cambrian formation, attained their maximum development in a number of species in the Silurian, and became mostly extinct in the Carboniferous period.

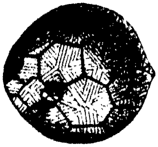

Fig. 69.—*Caryocystites*, a Cystidean.—After Lütken.

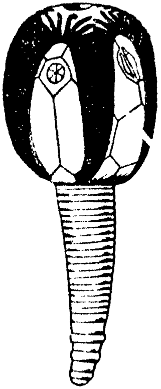

Fig. 70.—*Pseudocrinus*, a Cystidean.—After Lütken.

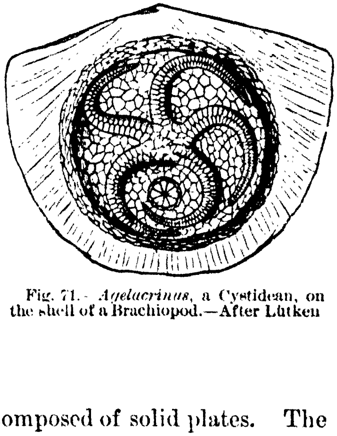

Fig. 71.—*Agelacrinus*, a Cystidean, on the shell of a Brachiopod.—After Lütken

CLASS I.—CRINOIDEA.

Spherical or cup-shaped Echinoderms, without a madreporic plate, usually attached by a jointed stem, a few free in adult life, with five arms subdividing into pinnulæ; the ambulacral feet in the form of tentacles arising around the mouth in the furrows of the calyx or situated on the jointed arms. In the Blastoidea and certain Cystideans the arms are absent, but the pinnulæ are usually present, though absent in Caryocystites. Circulatory, water-vascular, and sexual organs much as in other Echinoderms; the digestive canal ending in a distinct eccentric aperture.

Order 1. *Brachiata* (True Crinoids).—Calyx with large pinnulated arms, without dorsal calical pores, mostly stalked (Encrinus, Pentacrinus, Apiocrinus, Rhizocrinus, Holopus, Antedon, Actinometra, Phanogenia).

Order 2. *Blastoidea.*—Armless, but with five series of pinnulæ, and with a stalk (Pentremites. No living representatives).

Order 3. *Cystidea.*—Usually armed, with jointed pinnulæ, and a short stalk, the latter sometimes absent, as in Caryocystites. (All fossil forms, as Edriaster, Caryocystites, Sphæronites, etc.)

Laboratory Work.—The living Crinoids are great rarities, and few students have access even to alcoholic specimens. The recent researches on their internal anatomy have been made in large part by cutting thin sections for the microscope, and staining them with carmine, etc., after the methods of the histologist.

CLASS II.—ASTEROIDEA (*Star-fishes*).

General Characters of Star-fishes. — Having already studied the structure of the common star-fish, we are prepared to understand the classification of the class. The star-fishes have star-shaped, flattened bodies, with round or flattened arms, a madreporic plate, and two or four rows of ambulacral feet.

Order 1. *Ophiuridea* (Sand-Stars).—This division is characterized by the body forming a flattened disk, with cylindrical arms, the stomach not extending into the arms, and there is no intestine or anal opening. The ambulacral furrow is covered by the ventral shields of the tegument, so that the ambulacral feet project from the sides of the arm. They have no interambulacral spaces or plates. The ambulacral feet or tentacles do not have a sucker at the end, but are provided with minute tubercles. They move faster than the true star-fishes, the arms being more slender and flexible. The madreporic body is one of the large circular plates in the interambulacral spaces around the mouth. The external openings for the exit of the eggs form distinct fissures or slits, one on each side of each arm. The ovaries are situated in the body, not extending into the arms, the eggs being expelled into the perivisceral cavity, and thence finding their way out into the water through the interradial slits.* The Ophiurans are bisexual, but one species being known to be unisexual, viz., *Ophiolepis squamata,* according to Metschnikoff. While most Ophiurans pass through a metamorphosis, the young of *Ophiolepis ciliata* is developed within the body of the parent, adhering by a sort of stalk (Krohn). In *Ophiopholis bellis* development is direct, there being no metamorphosis.

An Ophiuran which has accidentally lost its arms can reproduce them by budding. Lütken has discovered that in species of *Ophiothela* and *Ophiactis* the body divides in two spontaneously, having three arms on one side and three on the other, while the disk looks as if it had been cut in two by a knife and three new arms had then grown out from the cut side. Simroth has made farther extended researches on self-fission in *Ophiactis.*

The Ophiurans in most cases undergo a decided metamorphosis like that of the star-fish, which will be described at length farther on. The larva, called a pluteus, is free-swimming, though in some species the young, in a modified larval condition, reside in a pouch situated above the mouth of the parent, finally escaping and swimming freely about (A. Agassiz).

In *Ophiocoma vivipara* Ljungman, which occurs in the South Atlantic, the young at first live in the body of the parent and afterward cluster on the surface of her disk. The eggs are hatched successively, the young being found in a regularly gradated series of stages of growth (Wyville-Thompson). It appears probable, as in the case of the sea-urchins, that the Ophiurans of the cooler portions of the South Atlantic, in most cases at least, have no metamorphosis. Several native forms are also viviparous.

Our most common sand-star is *Ophiopholis bellis* Lyman (Fig. 72), which may be found at low-water mark, and especially among the roots of Laminaria thrown up on the beach. It is variable in color, but beautifully spotted with pale and brown, its general hue being a brick-red. *Amphiura squamata* Sars has long slender arms and is white; it lives below tide-marks. The basket-fish, medusa's head, or *Astrophyton Agassizii* Stm., is of large size, the disk being two inches across, and the arms subdividing into a great number of tendril-like branches. It lives from ten to one hundred fathoms in the Gulf of Maine.

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* On the other hand, Ludwig denies that the eggs pass into the perivisceral cavity, but insists that they collect in pouches formed by an introversion of the integument.

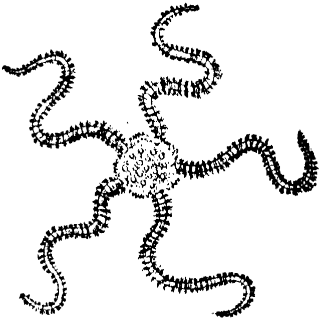

Fig. 72.—*Ophiopholis bellis*, common Sand-

Ophiurans are widely distributed, and live at depths between low-water mark and two thousand fathoms. Fossil Ophiurans do not occur in formations older than the Upper Silurian, where they are represented by the genera *Protaster*, *Palæodiscus*, *Acroura*, and *Eucladia*; genuine forms closely like those now living appear in the muschelkalk beds of Europe (Middle Trias).

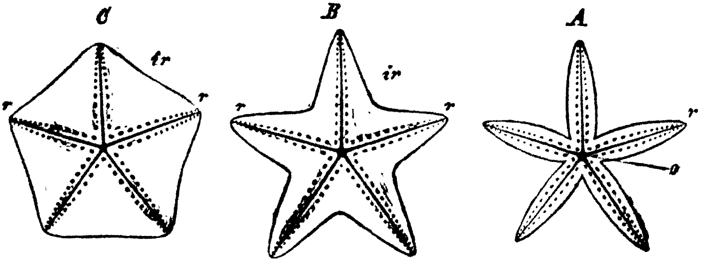

Fig. 73.—Three forms of Star-fish, *A*, *B*, *C*, seen from above, showing the different development of the ambulacral and interambulacral areas. The ambulacra are indicated by rows of dots; *o*, mouth; *r*, arms; *tr*, interradial or interambulacral areas. *C Pteraster; B*, *Goniodiscus; A*, *Asteriscus*.—After Gegenbaur.

Order 2. Asteridea.—In the true star-fishes the arms are direct prolongations of the disk, and the stomach and ovaries or spermaries project into them, and there is a deep ambulacral furrow, while the interambulacral spaces vary much in development (Fig. 73); the feet are provided with suckers, excepting those at the end of the arms, which are tentacle-like. We have already described the common star-fish of our north-eastern coast, *Asterias Forbesii* of Desor (Fig. 74). This and the allied varieties are abundant on mussel and oyster beds, being very injurious to the latter, which serve them as food. The star-fish projects its capacious stomach, turning it inside out, between the open valves of the oyster, and sucks in the soft parts, in this way doing much damage to the oyster-beds of the southern coast of New England.

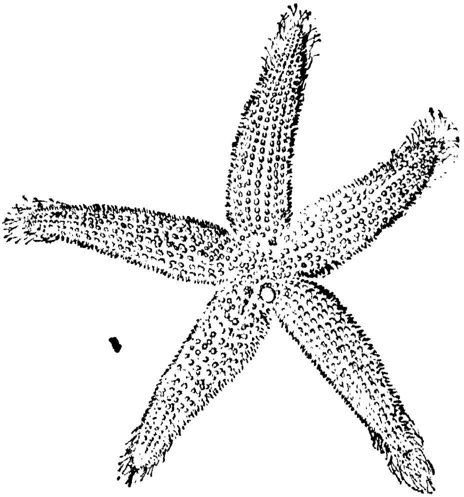

Fig. 74.—*Asterias Forbesii*, natural size.—After A. Agassiz.

The bodies of star-fishes as well as sea-urchins (Echini) are covered with *pedicellariæ*, which in the former are situated around the base of the spines on the upper side of the body. They are pincer-like, consisting of but two prongs. In the sea-urchins they are three-pronged, and scattered irregularly over the surface of the body. Their use is not really known.

The development of this species (and its ally or variety, *A. berylinus*) has been studied by A. Agassiz. After passing through the morula and gastrula stages, the cephalula or larval stage is reached, the mouth, digestive sac and its posterior opening being formed, a cephalic end being distinguished from a posterior end. The larva is now bilaterally symmetrical. At this time two lobes arise from each side of the mouth. These separate from their attachment and form two distinct hollow cavities, and by the time the larva attains the Brachiolaria stage the development of the body of the star-fish begins, for these two cavities subsequently develop into two water-tubes. On one of these cavities the back of the star-fish is afterward developed, while on the other the under side with the feet or tentacles arise. The fully-grown larva is called a *brachiolaria*, as it was originally described with this name under the impression that it was an adult animal, as was the case with the *plu-*

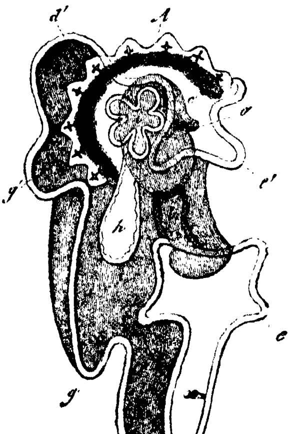

Fig. 75.—*Bipinnaria* with the star-fish budding from it. *e*, *e'*, *d'*, *g*, *g'*, protuberances of the body comparable with the "arms" of the Brachiolaria figured in the adjoining engraving. *b*, mouth; *o*, vent of the larva; *A*, germ of the star-fish; *h*, ciliated digestive tract; *i*, ambulacral rosette (germ of the water-vessels).—After Müller, from Gegenbaur.

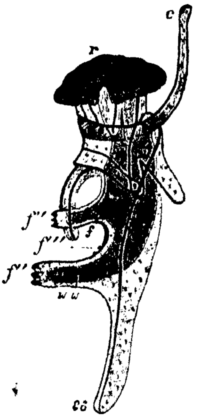

Fig. 76.—Brachiolaria of *Asterias vulgaris*, enlarged, with the star-fish (*r*) developing at the aboral end. *e*, median anal arm; *e*⁶, odd terminal oral arm; *f*, brachiolar arm; *f'*, branch of water-tube (*ww'*) leading into *f''* odd brachiolar arm; *f'''*, surface-warts at base of odd brachiolar arm *f''*.—After A. Agassiz.

teus of the sand-stars, the *bipinnaria* (Fig. 75) of certain star-fishes, and the *auricularia* of the Holothurians.

Fig. 76 shows the star-fish developing on the aboral end of the brachiolaria, whose body it is now beginning to absorb. The brachiolaria soon shrinks; falls to the bottom, and attaches itself by its short arms. The star-fish completely absorbs the soft body of the larva, and is conical, disk-shaped, with a crenulated edge. In this stage it remains probably two or three years before the arms lengthen and the adult form is assumed.

In *Leptychaster kerguelenensis* Smith, of the South Pacific, a form allied to *Luidia* or *Archaster*, the young develop directly in a sort of marsupium, according to Wyville-Thompson. *Pteraster militaris* was found by Sars to be viviparous.

In *Brisinga* the arms number from nine to twenty, are long, cylindrical, and, like the body, bear long spines. The species are abyssal. *B. endecacnemos* Asbjornsen lives on the Norwegian coast, at a depth of about 200 fathoms, and was dredged in abundance by the Challenger Expedition in 1350 fathoms, at a station due south of St. George's Banks, associated with other species of star-fish (*Zoroaster* and *Astropecten*), and again in eighty fathoms on La Have Bank, off Nova Scotia. A common form living in mud in usually from ten to thirty fathoms is *Ctenodiscus crispatus* Retzius, in which the body is almost pentagonal, the arms being very short and broad. *Archaster* is a genus of star-fishes occurring at great depths, *A. vexillifer* Wyville-Thompson (Fig. 77), occurring off the Shetland Islands, in from 300 to 500 fathoms. *Luidia* is called the brittle star-fish, as when brought up from the bottom and taken out of the water it breaks up into fragments. It has five long arms. *L. clathrata* is common on the sandy shores of the Carolinas, and ranges from New Jersey to the West Indies. *Astropecten articulatus* (Say) has the same range. *Astrogonium phrygianum* Parel is a large pentagonal, bright-red star-fish, living in twenty to fifty fathoms on rocky bottoms in the Gulf of Maine and northward; while *Pteraster militaris* Müller is an arctic species which ranges south to Cape Cod. It is subpentagonal, with five short arms. The fine large *Solaster endeca* Retzius has eleven smooth arms; it lives in deep water. *Crossaster papposus* (Müller and Troschel) is common on a rocky bottom, in from twenty to eighty fathoms, from the Gulf of Maine northward; it is bright red, and has thirteen to fourteen spinulated arms. *Cribella sanguinolenta* Lütken is a common species on the coast of New England below low-water mark, and is in some respects like *Crossaster*.

Fig. 77.—*Archaster vexillifer*, under side; natural size.—After Wyville-Thompson.

More closely allied to Asterias is the Pacific Coast *Pycnopodia helianthoides* Stimpson, which ranges from Sitka to Mendocino, Cal. It is very common in Puget Sound, under wharves. *Asterias vulgaris* Stimpson represents, on the northeastern coast, the *A. rubens* of Europe. *Asterias polaris* (M. and T.) has six arms, and is over twelve inches in diameter; it is very common from Labrador northward.

Fossil star-fishes allied in most respects to *Asterias* occur in the Lower Silurian rocks, showing the remarkable persistence of this type of the order. Characteristic Lower Silurian forms are *Palæaster* and *Archasterias.* In the Upper Silurian appeared *Palasterina,* a genus allied to the living *Astrogonium,* etc.

CLASS II.—ASTEROIDEA.

Echinoderms with a star-like or pentagonal body, with two or four rows of ambulacral feet or tentacles on the oral side. Body covered with small, short spines, often arranged in groups. The nervous system pentagonal, with nerves extending into the arms; the water-vascular and hæmal systems also radiating into the arms. Most of the species bisexual; the young usually passing through a metamorphosis, the star-fish budding out from the water-vascular system of the pluteus, bipinnaria or brachiolaria form, which previously passes through a morula, gastrula, and cephalula stage.

Order 1. *Ophiuridea.*—Arms round, starting suddenly from a round, disk-like body. Ambulacral furrow covered by a series of ventral plates, so that the tentacles or ambulacral feet are thrust out laterally. The ovaries and stomach not extending into the arms; no anal-opening, no pedicellariæ. (Ophiura, Ophioglypha, Ophiolepis, Amphiura, Ophiocoma, Astrophyton).

Order 2. *Asteridea.*—Body star-like, the arms being gradual extensions of the disk, and containing the reproductive glands, digestive cœca, as well as the radial nerves and radial hæmal and water-vascular canals. A deep ambulacral furrow, containing two or four rows of ambulacral feet or tentacles, those at the extremity of the arms without suckers (Brisinga, Ctenodiscus, Luidia, Astropecten, Oreaster, Astrogonium, Pteraster, Solaster, Crossaster, Cribrella, Pycnopodia, Asterias).

Laboratory Work.—The larger star-fishes are easily dissected; the general relations of the integument may be perceived by making transverse and longitudinal sections, while the viscera may be studied by splitting the body and arms in two vertically. The smaller Ophiurans can be hardened in alcohol, and stained sections made for studying the intricate relations of the water-vascular, hæmal, and nervous systems.

CLASS III.—ECHINOIDEA (*Sea-urchins*).

General Characters of Sea-Urchins.—A good idea of the general structure of the members of this class may be obtained by an examination of the common sea-urchin, *Echinus* (Fig. 78), of the eastern coast of the United States, Northern Europe, and the Arctic Seas. It is common among rocks, ranging from low-water mark to fifty or more fathoms. It eats sea-weeds, and is also a scavenger, feeding on dead fish, etc. We have observed great numbers of them assembled in large groups, feeding on fish offal, a few fathoms below the surface, in a harbor on the coast of Labrador, where fishing-vessels were anchored.

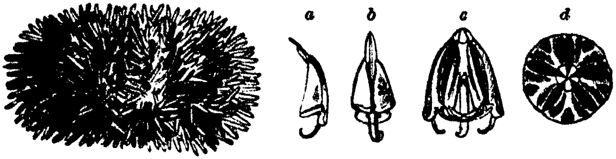

Fig. 78.—The common Sea-urchin, *Echinus* (Strongylocentrotus) *d*, frame-work of mouth and teeth seen in front; *c*, the same seen sideways; *a*, *b*, side and external view of a single tooth (pyramid); all natural size.—After Morse.

On placing an Echinus in sea-water the movements of the animal, especially its mode of drawing itself along by its numerous long tentacles or ambulacral feet, and how it covers itself by drawing together bits of sea- and gravel, may be

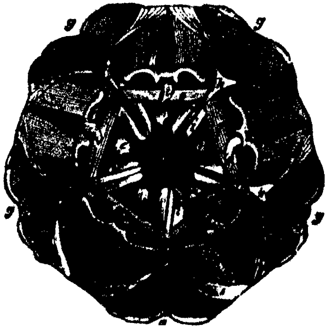

Fig. 79.—Tooth-apparatus of the Sea-urchin, showing the complicated arrangement of the muscles.—From Macallister.

A habit less easily detected is that of some sea-urchins burrowing in limestone rocks and coral reefs until the animal sinks quite far down. How the rock becomes thus worn away, unless simply by the rotary movements of the body, is not clearly understood.

In order to examine the external anatomy, the shell should be deprived of its spines in part, meanwhile observing the mode of attachment of the spines, of which microscopic sections should be made. The solid mouth-parts, the oral membrane surrounding the five sharp conical teeth or "pyramids," and their mode of attachment to the "auricles" in the shell, should be thoroughly investigated, as well as their relations to the mouth-opening and the digestive canal. The shell is a flattened sphere, consisting of ambulacral plates, perforated for the exit of the feet, and a broader series of five rows of interambulacral plates to which the spines are attached, and of such form and arrangement as to give the greatest possible strength and lightness to the shell (Figs. 80, 81, 82). The outlet of the alimentary canal is situated on the aboral (abactinal) or upper end of the shell, while the madreporic plate is situated upon the top or end of the shell (as the animal moves mouth downward), being a modification of one of the genital plates (Fig. 81, *m*). There are five large plates, one at each end of the interambulacral zones meeting on the aboral end of the body; in them are the ovarian openings through which the eggs escape; these

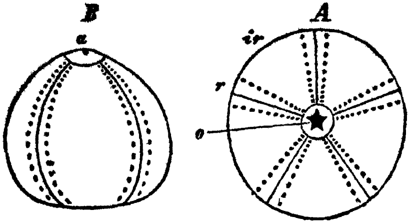

Fig. 80.—Schematic figures of a Sea-urchin. *A*, from the oral end; *B*, from one side. Ambulacra indicated by rows of dots. *r*, ambulacral; *ir*, interambulacral areas; *o*, mouth; *a*, vent.—After Gegenbaur.

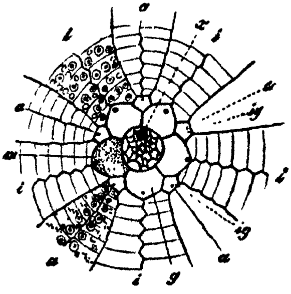

Fig. 81.—Aboral end of the shell of an *Echinus*, with the upper end of the rows of plates. *a*, ambulacral area; *i*, interambulacral area; *g*, genital plates; *ig*, intergenital plates; *m*, one of the genital plates forming a madreporic plate; *x*, anal opening in the aboral area surrounded by the genital plates. The tubercles to which the spines are attached are only drawn on one ambulacral and one interambulacral area; on the former are also drawn the pores through which the suckers protrude.—After Gegenbaur.

five plates are called the genital plates, while in each of the five smaller plates at the end of each ambulacral series is an eye-speck. The pedicellariæ are three-pronged, knob-like spines, scattered over the body, especially near the mouth. They partly serve to remove the fæcal matter, but their main function is not known.

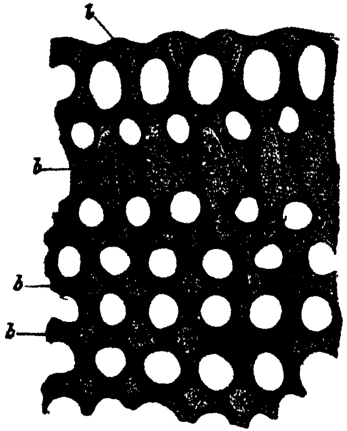

Fig. 82.—View of the calcareous net-work from a plate of the integument of a Sea-urchin (*Cidaris*). *b*, section perpendicular to the horizontal net-work of straight rods.—After Gegenbaur.

Besides the pedicellariæ, Lovén has discovered on most living Echini, with the exception of *Cidaris*, small button-like bodies called *sphæridia*, situated on a short stalk, moving on a slightly marked tubercle. They are supposed to be sensorial, probably organs of taste.

The internal anatomy of the sea-urchin may be best studied by cutting the shell into two halves, oral and aboral. Removing the aboral end, the digestive canal may be seen in place.

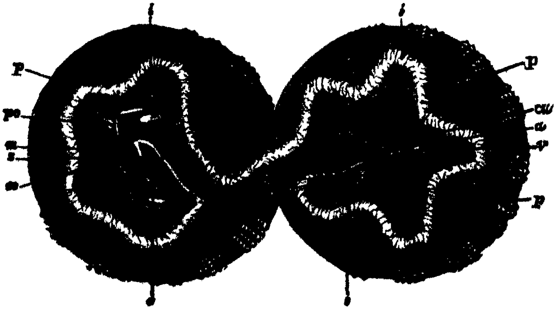

Fig. 83.—Shell of a Sea-urchin (*Strongylocentrotus lividus*). *a*, anus; *os*, œsophagus; *i*, intestine; *s*, one of the rods of the tooth-apparatus; *m*, muscles of the jaws; *p*, vessels of the sucking feet; *po*, extremity of the water-vessel; *ca*, ocular plate; *v*, ovary.

It consists of a narrow œsophagus (Fig. 83, *œ*), more or less pentagonal near the mouth, dilating into the stomach; and of a terminal intestine. The long stomach passes from left to right around the interior of the body, then turns up toward the aboral end, and curves back in the opposite course, again passing around the body from right to left, forming two series of loops partly enclosing the ovaries; it is held in place by a broad, thin membrane or "mesentery." The reproductive and other organs are much as described in the star-fish, there being five ovaries or spermaries, the sexes being distinct. The nervous ring around the mouth sends off five nerves along the ambulacra, which are accompanied by a water-vascular canal sending branches to the tentacles, and a pseudo-hæmal canal, there being an oral and aboral (anal) hæmal ring (their presence is denied by Hoffmann), as well as an oral water-vascular ring, with five Polian vesicles (present only in the true Echini and Clypeastroids), a stone-canal and a fusiform tube or "heart"* next to it, while the alimentary canal is accompanied by two hæmal vessels, one on the "dorsal" and the other on the free or ventral side, communicating with a lacunar network in its walls.

In Echinus it is difficult to perceive any bilateral symmetry, the parts radiating, as in the star-fish, from the centre; but in the *Spatangus* and allied forms it is easy to divide the animal into a right and left side, and the body is more or less elongated, as in *Pourtalesia* (Fig. 87), the mouth being situated at one end and the anus at the other.

The mode of development of the common sea-urchin (Fig. 78) has been discovered by Mr. A. Agassiz. The earliest stages are much as described in the star-fish. The form of the pluteus larva is quite remarkable, there being eight very long slender arms supported by slender calcareous rods projecting from the body, and, during the movements of the animal, opening and shutting like the rods of an umbrella. The body is provided with a sinuous row of vibratile cilia. When the larva is twenty-three days old the rudiments of the five tentacles of the sea-urchin appear. By this time the pluteus-form is acquired, and also at this period the sea-urchin growing upon the deciduous pluteus scaffolding has concealed the shape of the digestive cavity of the larva, and the spines are so large as to conceal the tentacles. The body of the pluteus is gradually absorbed by the growing sea-urchin; the spines and suckers of the latter increasing in size and number with age, until by the time the larval body has disappeared the young Echinus is more like the adult than the star-fish at the same period in life. Grube has found that *Anochanus sinensis*, supposed to have come from the Chinese or East Indian seas, has no metamorphosis; while *Hemiaster cavernosus* of Chili was found by Philippi to carry its young in marsupia and to develop directly.

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* It should be observed that the latest and best observers are at variance regarding the structure and function of the so-called Echinoderm "heart."

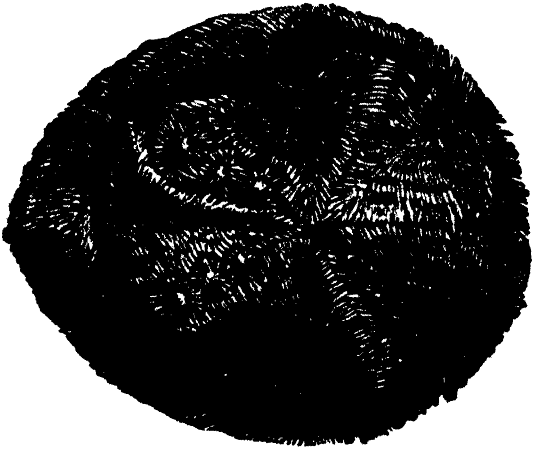

Fig. 84.—*Hemiaster Philippii*, with the young in two of the marsupia.—From Wyville-Thompson's Voyage of the Challenger.

Several species of sea-urchins in the cooler portions of the South Atlantic, especially at the Falkland Islands and Kerguelen Island, also develop directly in marsupia or brood-hollows, without passing through a metamorphosis. In *Hemi-*

aster Philippii Gray (Figs. 84 and 85), from the latter island, certain of the ambulacral plates are greatly expanded and depressed "so as to form four deep, thin-walled oral cups, sinking into and encroaching upon the cavity of the test, and forming very efficient protective marsupia." The spines are so arranged that a kind of covered passage leads from the ovarial opening into the marsupium, and along this passage the eggs, which are very large (a millimetre in diameter) are passed and arranged in rows, each egg being kept in place by two or three spines bending over it. Here the eggs develop, and the embryos, after the calcareous plates once begin to develop, rapidly assume the parent form; when they leave the marsupium they are about two and a half millimetres long. In *Cidaris nutrix* Wyville-Thompson the eggs are protected in a sort of tent by certain spines near the mouth. Here the young develop without a metamorphosis. The allies of these forms in the Northern Atlantic are either known or supposed to be metabolous; and Sir Wyville-Thompson states that no free-swimming Echinoderm larvæ (pluteus, etc.) were seen by the Challenger Expedition in the Southern Ocean.

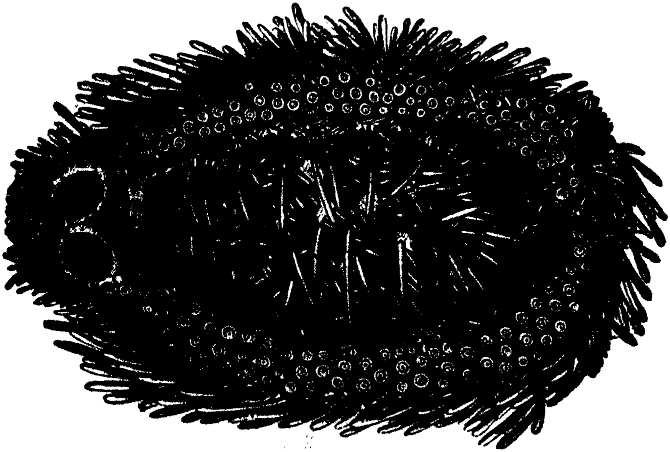

Fig. 85.—Marsupium of *Hemiaster Philippii*, containing eggs. Much magnified.—From Wyville-Thompson's Voyage of the Challenger.

Taking a rapid survey of the principal forms of sea-urchins, we may divide the class of *Echinoidea* into two orders: the *Palechinida*, or older sea-urchins, in which the shell is composed of more than twenty rows of plates; and the *Autechinida* with twenty rows of plates.*

Order 1. *Palechinida.*—Comprises first the suborder *Melonitida*, in which there are more than ten rows of ambulacral plates, represented by *Melonites* of the coal formation, and *Protechinus*, *Palæchinus*, *Archæocidaris*, etc. In the second suborder *Eocidaria*, there are ten rows of ambulacral plates. A type of the group, *Eocidaris Kaiserlingii*, appears in the Permian formation.

Order 2. *Autechinida.*—To this division belong sea-urchins with twenty rows of plates. The first suborder is the *Desmosticha*, comprising those sea-urchins with band-like ambulacra extending from the mouth to the opposite extremity, and of more or less regular, flattened, spherical form. Such are *Cidaris*, *Echinus*, *Echinometra*, *Clypeaster*, and *Echinarachnius*. The *Echinus esculentus* Linn., of the Mediterranean Sea, is as large as an infant's head, and is used as an article of food.

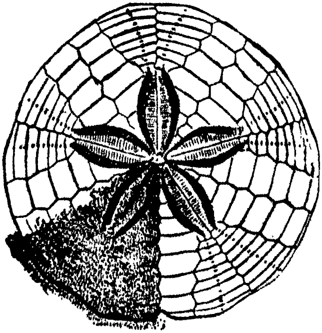

Fig. 86.—*Echinarachnius parma*, common Sand-cake. Natural size.—After A. Agassiz.

In *Clypeaster* the body is large and the shell very solid. *C. subdepressus* Agassiz is common on the Floridan coast. An orbicular flattened type are the sand-cakes, of which the *Echinarachnius parma* Gray (Fig. 86) is abundant in the shallower portions of the North Atlantic, from low-water mark to forty fathoms. It is replaced southward from Nantucket to Brazil by *Mellita testudinata* Klein.

The last suborder, *Petalosticha*, is characterized by the leaf-like ambulacra, and the irregularly heart-shaped, often elongated, form of the shell, an anterior and posterior end being well defined. They for the most part live buried in the sand or sandy mud, not moving about so actively as the *Desmosticha.*

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* These are terms proposed by Haeckel, who regards these divisions as subclasses, but we think they should more properly be called orders.

Of the family *Spatangidæ* the singular genus *Pourtalesia* (Fig. 87, *P. Jeffreysii* Wyville-Thompson) deserves notice, the species of which are bottled-shaped, with a thin, transparent shell. The transition from such a form as this to the Holothurians is not a very extreme one. This genus, A. Agassiz states, is the living representative of *Infulaster* of the Cretaceous period. *P. miranda* A. Agassiz was dredged in the Florida Straits, in about three hundred and fifty fathoms, and by British naturalists in the Shetland Channel. *P. Jeffreysii* was dredged in six hundred and forty fathoms, near the Shetland Islands.

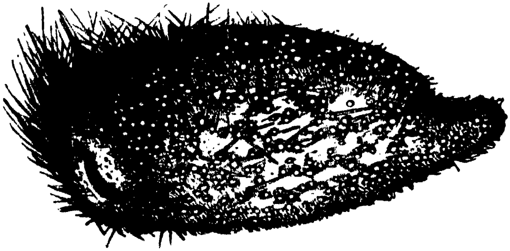

Fig. 87.—*Pourtalesia Jeffreysii*, slightly enlarged.—After Wyville-Thompson.

Spatangus is distinctly heart-shaped, as is *Hemiaster.* An interesting deep-sea or abyssal form not uncommon in deep soft mud, at the depth of one hundred fathoms, off the coast of Maine and Massachusetts, and extending from Florida around to Norway, is *Schizaster fragilis* Agassiz.

Echinoderms range to a great depth in the ocean, and are largely characteristic of the abyssal fauna of the globe. In space they are widely distributed, there being but two Echinid faunæ on the eastern coast of the United States, one arctic, the other tropical. While a large number of species characterize the arctic or circumpolar regions, the larger proportion of species are tropical and subtropical. Mr. A. Agassiz divides the Echinid fauna of the world into four realms: the American, Atlantic, Indo-Pacific, and Australian.

Though Crinoids were the predominant type of Echinoderms in the palæozoic rocks, a few star-fish and Ophiurans appeared in the Upper Silurian period, and with them were associated one species of sea-urchin, *Palæchinus*, though the genus was more numerously represented in the Coal period. Some Palæozoic forms resembled the living genera *Calveria* and *Phormosoma*, and belong to the extinct Carboniferous genera *Lepidechinus* and *Lepidesthes*; in all these forms, fossil and recent, the interambulacral plates overlapped one another so as to give a certain amount of flexibility to the shell. This feature existed in a less degree in *Archæocidaris*. The characteristic American carboniferous genera are *Melonites*, *Oligoporus*, and *Lepidechinus*. The Permian *Eocidaris* is nearly allied to *Archæocidaris*, so that it is a true palæozoic type (Nicholson).

In the Mesozoic epoch (Trias, Lias, and Jura) appeared a more modern assemblage of *Spatangidæ*, and genera such as *Hemicidaris* and *Hypodiadema*, closely allied to the *Cidaridæ* proper, appeared in the Trias. The Jurassic beds are characterized by genera allied to *Diadema, Echinus, Cidaris*, and a number of species of the families *Cassidulidæ* and *Galeritidæ*. A large number of genera survived in the Cretaceous period, which, however, is characterized by the marked development of the *Spatangidæ*. In the Upper Cretaceous the earliest *Clypeastridæ* appeared, while the Tertiary Echinid fauna is quite similar to the present one. The striking fact in the geological history of the class is the persistence of many of the cretaceous genera in the abyssal or deep-sea fauna of the present time (A. Agassiz).

CLASS III.—ECHINOIDEA.

Spherical, heart-shaped, or disk-like Echinoderms, with a solid shell of immovable plates, bearing interambulacral spines; with a mouth and anal opening, the mouth in most of the species armed with five teeth; ambulacral feet well developed. The sexes distinct. Development either direct, or, as in most cases, by a marked metamorphosis from a pluteus larva.

Order 1. *Palechinida.*—Shell composed of more than twenty rows of plates. Suborder 1. *Melonitida* (Melonites, Protechinus, Palæchinus, Archæocidaris). Suborder 2. *Eocidaria* (Eocidaris).

Order 2. *Autechinida.*—Shell composed of twenty rows of plates. Suborder 1. *Desmosticha* (Cidaris, Echinus, Strongylocentrotus, Echinometra, Clypeaster, and Echinarachnius). Suborder 2. *Petalosticha* (Echinobrissus, Anochanus, Pourtalesia, Spatangus, and Schizaster).

Laboratory Work.—We have already given some hints as to the mode of dissecting sea-urchins, which should be done under water in deep pans. Great care must be taken in removing the digestive canal, which is very delicate in itself, and usually filled with sand. In studying the water-vascular and blood-vessels, careful, skilful injections with carmine are indispensable. The spines may be studied by making thin longitudinal and transverse sections. The test, or shell, should be denuded of the spines in order to study the relations of the ambulacral, interambulacral, and genital plates.

CLASS IV.—HOLOTHUROIDEA (*Sea-cucumbers*).

General Characters of Holothurians.—We now come to Echinoderms in which the body is usually long, cylindrical, with a tendency to become worm-like, and in certain genera, as *Synapta, Chirodota,* and *Eupyrgus,* it is difficult both in their larval stages (*Synapta*) and in the external and internal anatomy of the adults to separate them from worms like *Sipunculus;* authors have therefore been led to the adoption of one of two views: first, either that the worms and Echinoderms have had a common origin, and the latter, though truly radiate, have no near affinities (though strong analogies) with the Cœlenterates, or the resemblance between the two branches (Echinoderms and worms) is one simply of analogy, and involves no blood-relationship. On the other hand the radiated arrangement of parts and the development and relations of the water-vascular system ally them, through the Ctenophores, with the *Actinozoa* and *Hydroida*, and it seems more natural to regard the Echinoderms as forming a branch of animals intermediate between the Hydroida and the worms, there being certain low worms with a water-vascular system.

But the student will be better able to appreciate these general questions after a more or less thorough acquaintance with the forms and structure of the present group. For this purpose he should first examine living sea-cucumbers, and then carefully dissect them. A detailed study of the anatomy of a *Pentacta* or a *Holothuria*, one a northern the other a subtropical and tropical form, and of a *Synapta*, found everywhere along our coast in sand below tide-marks, will give the groundwork; and this knowledge, autoptically acquired, can then be corrected and extended by reading monographs or compiled statements to be found in the more authoritative general works on comparative anatomy.

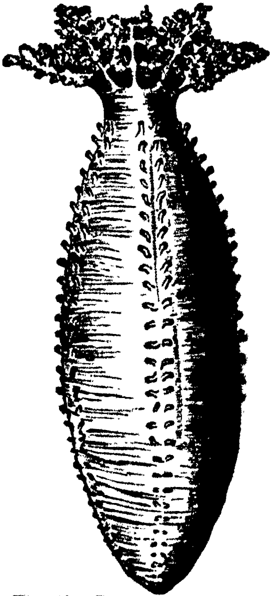
Fig. 88.—*Pentacta frondosa*.—From Tenney's Zoology.

Living Holothurians can be procured with the dredge or dug out of the sand between tide-marks. They should be kept in aquaria, and their movements watched as well as their mode of locomotion, and the action of their branchiæ or external gills (tentacles).

The common sea-cucumber, north of Cape Cod, and extending through the Arctic regions around to Great Britain, is *Pentacta frondosa* Jaeger (Fig. 88). It lives from extreme low-water mark to a depth of fifty fathoms. It is of a tan-brown color, from six inches to nearly a foot in length, and in its form and the corrugations of its tough, leathery skin resembles a cucumber in nearly all respects except color. There are five series of ambulacral feet, each series consisting of two irregular rows. Around the mouth is a circle of ten much-branched tentacles or gills (homologous with the ambulacral feet).

On laying the body open by making a cut extending from the mouth to the vent, the thick muscular walls of the body may be observed, and the general relations of the viscera to the body-walls, which have nothing of the radiate arrangement of parts, so clearly marked in the other Echinoderms, the ambulacra, tentacles, and longitudinal muscles alone being arranged in a radiate manner.* Unlike other Echinoderms, the madreporic body is internal, and there is a capacious cloaca or rectum, and a large vent.

On the inside of the body-walls are numerous small circular (transverse) muscles forming slight ridges, which serve to contract the body, and five double large longitudinal muscles (Fig. 89, *l*) lying in the ambulacral zones. The mouth is surrounded by a muscular ring, from which arise ten large, much-branched tentacles. The pharynx, or the portion corresponding to "Aristotle's lantern," of the sea-urchin is broad and short, with five large retractor muscles (*r*) originating from the ambulacral or longitudinal muscles on the anterior third of the body. The stomach is short, not much wider than the intestines, with well-marked transverse folds within. The intestine (*i*) is several times longer than the body, with longitudinal small folds, and held in place by a large, broad mesentery which accompanies the intestine through the greater part of its length. The intestine terminates suddenly, in a large cloaca (*c*), from which n one side arises the "respiratory tree," which has but one nain stem, and is only occasionally held in place by musular threads. The branches are numerous, and are smaller

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* In *Eupyrgus* and *Echinocucumis* it is difficult to perceive any radiation in the body except in the unbroken circle of tentacles, while in Sipunculus and allied worms (*Gephyrea*) the tentacles form a complete circle, and these worms have a ring-canal and an imperfect or rudimentary system of vessels thought by some authors to correspond to the water-vascular system of Echinoderms.

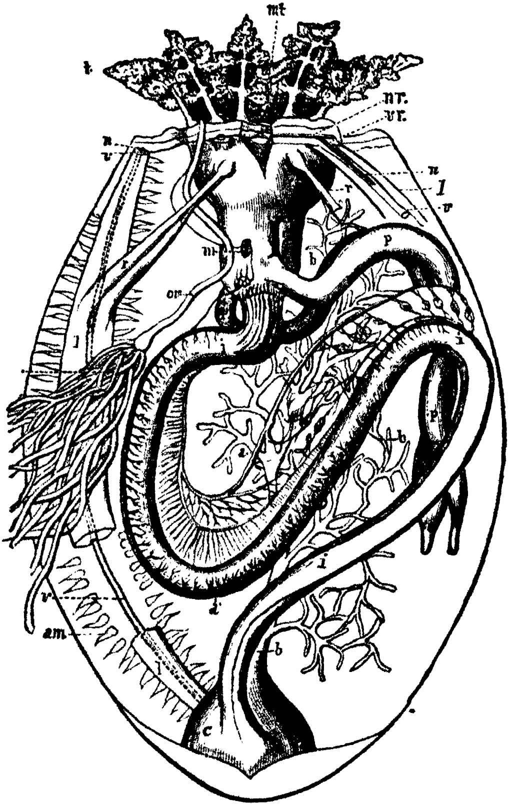

Fig. 89.—*Pentacta frondosa.* *t*, tentacles; *l*, longitudinal muscles; *r*, retractor muscles of the tentacular system; *i*, intestine; *c*, cloaca; *b*, respiratory tree; *vr*, water-vascular ring or ring-canal, *v*, radial water-vascular canal; *m*, madreporic body; *pp*, polian vesicles; *am*, ampullæ; *a*, *a'*, pseudo-hæmal contractile vessels (from Carus); *o*, ovary; *ov*, oviduct.—Drawn by J. S. Kingsley from a dissection made by the author.

and paler than the ovarian tubes. The water enters the cloaca (*c*), passes into the respiratory tree (*b*), oozes out of the ends of the branches, filling the body, whence it is taken up by the madreporic body and carried into the water-vascular system by the narrow duct on the left side of the pharynx. Besides being respiratory, this organ is supposed to be depuratory in its function. In some Holothurians certain organs (the Cuvierian organs), supposed by Semper to be organs of defence, as they are readily thrown out when the animal is disturbed, are attached either to the stem of the respiratory tree or to the cloaca. The madreporic body (*m*) forms a rosette, partly surrounding the membrane attached to one side of the pyloric end of the stomach, and leads by the madreporic canal, which is closely bound down to the pharynx, to the ring-canal (*vr*). Also connected with the ring-canal are two enormous Polian vesicles (*p*, *p*), which are nearly two thirds as long as the body; by slitting up their base with scissors they can be followed to the ring-canal. The latter (*vr*) is a capacious canal surrounding the mouth, and can be detected by laying open the oral-opening, and then by cutting across the longitudinal muscles (as at *v*) the radial vessels may be followed along the body under the muscles. Just above the ring-canal is situated the nervous ring (*nr*), and its radial nerves (*n*) can be traced along and outside of the radial water-vascular canals. The ampullæ (*am*) are red, conical, flask-shaped, conspicuous organs, lying irregularly, a row on each side of each longitudinal muscle. They are filled with water from the small lateral vessels of the radial water-vascular canals. The single ovary is composed of a large mass of long tubes, which are larger than and tangled up with the branches of the respiratory tree. The oviduct is attached by a membrane to the stomach, and opens between two of the tentacles on the edge of the mouth.

The blood or pseudo-hæmal vessels* are difficult, without very fine dissections, to be made out. The system consists of a plexus of vessels lying next to the ring-canal, from which two vessels (*a*, *a'*) pass along opposite sides of the intestine. A fluid containing nucleated cells fills both the pseudo-hæmal and water-vascular canals.

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* These vessels in Fig. 89 have been copied from Carus' Icones Zootomicæ; in other respects the drawing represents the anatomy of *P. frondosa*.

Holothuria floridana Pourtales is a large, dark-brown sea-cucumber, with the feet scattered irregularly over the body, and with smaller tentacles than in *Pentacta,* which is abundant just below low-water mark on the Florida reefs, and grows to about fifteen inches in length. The alimentary canal is filled with foraminifera and pieces of shells, corals, etc.; it is about three times the length of the body, and ends in a much larger cœcum than that of Pentacta. There are two widely separated branches of the "respiratory tree," one being free, and the other, tied to the body-walls by thread-like muscular attachments, extends to the pharynx. The pharynx is calcareous, while in Pentacta it is muscular. On the madreporic body is a group of about thirty pyriform stalked bodies, the longest, including the stalk, about a quarter of an inch in length. Succeeding these bodies, and situated on the madreporic canal, leading to the ring-canal, are a large number of Polian vesicles, the largest one an inch in length. The duct passes spirally nearly round the œsophagus, and empties into the ring-canal by the ducts nearly a quarter of an inch apart. In connection with the tentacles or branchiæ are twenty long, slender tentacular ampullæ, not present in Pentacta and *Thyone.* The ovarian tubes are very small, some enlarging and bilobate at the end.

Closely allied in external form to *Holothuria floridana,* though belonging to a different family (including Pentacta), is *Thyone briareus* (Lesueur), which lives just below tidal marks, from Long Island Sound to Florida. In this genus the ambulacral feet are not arranged in rows, but scattered over the surface of the body. This species is very common, and as it is more accessible to the student than any other of the sea-cucumbers, we give some points in its anatomy as compared with Pentacta, with which it is more closely allied than to *Holothuria.* In a specimen about eight centimetres (three inches) long the intestine is over two metres (about seven feet) long, the œsophagus opening into an oval stomach less than an inch in length. The tentacles are capable of being very deeply retracted, and as in Pentacta there are no tentacular ampullæ. The small madreporic body is much as in Pentacta, and connects with a duct (madreporic canal) leading to the ring-canal. There are three Polian vesicles, one fusiform and an inch in length, the two others slenderer. The cloaca is of moderate size, as in Pentacta, and the respiratory trees divide at once into two very bushy branches. The ovarian tubes form a brush or round broom-like mass or tuft, about an inch long, the tubes small, yellow, and of nearly uniform length, the oviduct straight and bound down to the walls of the body.

We might here mention the most aberrant type of Holothurians, the *Rhopalodina* described by Semper, who states that the body is flask-shaped, with the mouth and vent situated near each other on the smaller end of the body. The mouth is surrounded by ten tentacles, and there are ten papillæ around the anus. There is a spacious cloaca or respiratory tree. "Ten ambulacra diverge from the centre of the enlarged aboral end of the body, and extend like so many meridians to near the commencement of the neck of the flask. In correspondence with each ambulacrum is a longitudinal muscular band; and it is an especial peculiarity of *Rhopalodina* that five of these are attached to the anal circlet, and five to the circum-œsophageal circlet" (Huxley).

The earlier stages of development of Holothurians, so far as known, is like that of star-fishes. The larva when fully grown is called an *auricularia.* It is transparent, cylindrical, annulated, with four or five bands of cilia, and usually with certain ear-like projections, from which it derives the name originally given to this larval form. Before the auricularia is fully formed the young Holothurian begins to bud out from near the side of the larval stomach, the calcareous, cross-like spicules appear, and the tentacles arise. The ear-like projections disappear, the auricularia thus becoming cylindrical. It is soon absorbed by the growing Holothurian, which in some genera is strikingly worm-like, and it seems that the Holothurian is more directly developed from the larva than in the case of the star-fish and sea-urchins, the metamorphosis being less marked—*i.e.*, growth is more continuous, as in the Crinoids.

In *Holothuria tremula* and *Synaptula vivipara* there has been observed a very slight metamorphosis, the young developing directly in a marsupium, as in the star-fishes and sea-urchins. *Cladodactyla crocea* Lesson, of the Falkland Islands, according to Sir Wyville-Thompson, carries its young in a sort of nursery, being "closely packed in two continuous fringes adhering to the water-feet of the dorsal ambulacra." He also found that in *Psolus ephippifer* Wyville-Thompson, which is covered with calcareous plates, there is a dorsal group of larger tessellated plates, each supported by a broad pedicel embedded in the skin. Under these mushroom-like plates brood-cavities or cloister-like spaces are left between the supporting columns, and in this architectural marsupium the embryos directly develop into sea-cucumbers. It follows that in all free-swimming Echinoderm larvæ, there is a true metamorphosis as distinct as in the butterfly, while in other forms in which development is direct the embryo is sedentary and lacks the cilia and various appendages so characteristic of the ordinary larval Echinoderms; thus there are different stages in the different classes of Echinoderms between direct development or continuous growth, and a complete metamorphosis like that of the star-fish or sea-urchin, in which the pluteus or larva is but a temporary scaffolding, as it were, for the building up of the body of the adult.

Turning now to the classification of the Holothurians, and beginning with the lowest, simplest, most generalized forms (which are also remarkably worm-like), and ascending to higher or more complicated forms, we find that there are two orders, those without feet (*Apoda*) and those with ambulacral feet (*Pedata*).*

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* It is possible that the Holothurians should be divided into two sub-classes, one *Diplostomidea* Semper, in which the body is spherical and the mouth and anus are close together, with ten ambulacral rows, etc., and the normal, cylindrical, bipolar Holothurians. Semper's *Diplostomidea* is based on *Rhopalodina lageniformis* Gray, from the Congo Coast, and regarded by Semper as the type of a fifth class of Echinoderms.

Order 1. *Apoda.*—The simplest apodous form is the *Eupyrgus scaber* Lütken, in which the body shows no external signs of longitudinal muscles, though there are five small ones, and is covered with spine-like, soft papillæ bearing calcareous plates. We have dredged it frequently on the coast of Labrador in shoal-water. It has a circle of fifteen unbranched tentacles, and is about one centimetre long. It also occurs in Greenland and Norwegian waters. *Myriotrochus* has a transparent skin dotted with minute white spots, which, when magnified, appear to be wheel-like, calcareous plates. It has a single Polian vesicle, and there is no respiratory tree nor Cuvierian appendages (Huxley). We have dredged this beautiful form (*M. Rinkii* Steenstrup) in sand, in shoal-water, on the coast of Labrador. A very common Labrador Holothurian is *Chirodota læve* Grube (Fig. 90). It lives in shallow, sandy, retired bays, and is whitish-gray, with five distinct muscular bands and scattered white spots, which are calcareous, wheel-like bodies situated in the skin.

Near *Synapta,* is *Leptosynapta Girardii* (Verrill), our common east coast species, which lives in sand at low tide. The body is very long, and the animal when disturbed constricts its body and breaks up into several pieces. The skin contains perforated plates and anchor-like bodies (Fig. 91). In this genus and those previously mentioned, constituting the suborder *Apneumona* and family *Synaptidæ,* the sexes are united in the same individual, and there is no respiratory tree, while the tentacles are simply digitated or lobulated.

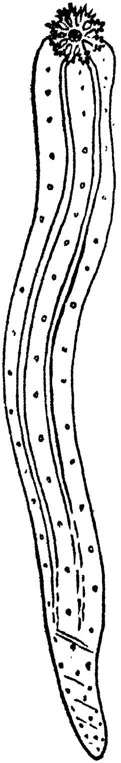


Fig. 90.—*Chirodota læve.* Half natural size. *a*, mouth, closed.

The next suborder, *Pneumophora,* forming the family *Molpadidæ,* is characterized by having a respiratory tree. In *Caudina* the skin is rough with calcareous pieces, the body ends in a long, tail-like prolongation; *C. arenata* Stimpson has fifteen four-pronged tentacles; it is commonly thrown up on the beaches of Massachusetts Bay. A deep-water form, a member of the abyssal fauna, is *Molpadia turgida* Verrill, which we have dredged in over one hundred fathoms in the Gulf of Maine, and which ranges southward to Florida. It has a head-end like the neck of a bottle, and the end of the body suddenly contracts into a tail, with a very small anus. There are fifteen tentacles.

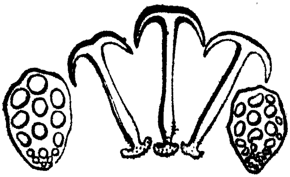


Fig. 91. — Hooks and plates of *Synapta Girardii*.—After Verrill.

Order 2. *Pedata*, or Holothurians with feet. The members of the first family (*Dendrochirotæ*) have tree-like, branching tentacles, retractor muscles, without Cuvierian organs. It is represented by *Thyone* and *Pentacta*, while here belong also *Lophothuria Fabricii* Düben and Koren, *Psolus phantapus* and *P. squamatus*, in which the body is armed with heavy calcareous plates, and the feet are confined to a ventral creeping disk.

In the highest family, *Aspidochirotæ*, there are tentacular ampullæ; the left respiratory tree is bound to the body-walls, and there is a single ovary, while Cuvierian organs are present. *Holothuria* is the type of the group. *H. edulis* Lesson, of the Moluccas and Australia, and *H. tremula* forms, when dried, the trepang sold in Chinese markets. Our *H. floridana* has been dried and exported to China as an article of food.

In their geographical distribution the *Apoda* are mostly boreal and arctic. Of the *Pedata*, the *Dendrochirotæ* are mostly northern or arctic, while the highest group, *Aspidochirotæ*, are mainly tropical. Certain genera (*Holothuria*, *Thyone*, *Psolus*, *Pentacta*, *Chirodota*, and *Synapta*) are almost cosmopolitan.

A few forms attain a great depth, and certain abyssal forms are often highly colored. One species, *Synapta* *similis*, lives in brackish water, according to Claus. Supposed plates of Holothurians have been found in the Jurassic rocks.

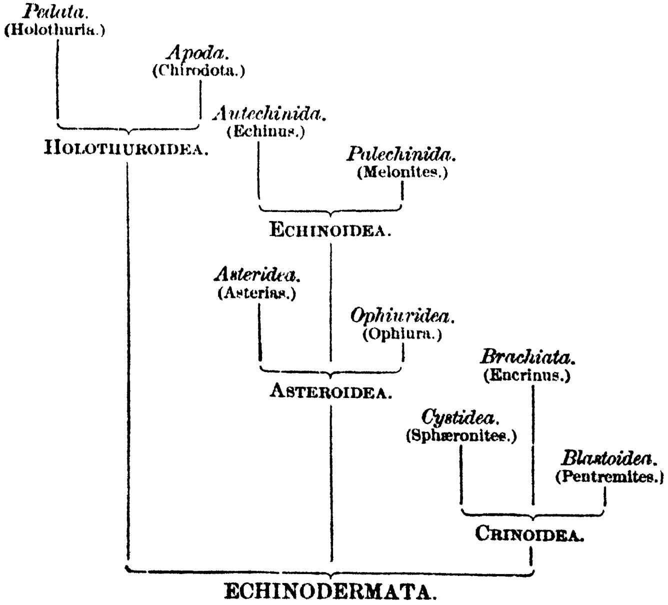
CLASS IV.—HOLOTHUROIDEA.

Worm-like, cylindrical Echinoderms, with a muscular body-wall usually containing calcareous bodies; with a circle of branched tentacles, a terminal opening of the intestine, madreporic plate internal, and usually a respiratory cæcal appendage. Unisexual or bisexual, developing by a metamorphosis from cylindrical, auriculated, free-swimming larvæ; or ametabolous.

Order 1. *Apoda.*—No ambulacral feet. Family 1. *Synaptidæ* (Eupyrgus, Chirodota, Synapta). Family 2. *Molpadidæ* (Caudina, Molpadia).

Order 2. *Pedata.*—Respiratory tree present, and the ambulacral feet. Bisexual. Family 1. *Dendrochirotæ* (Thyone, Psolus, Echinocucumis, Pentacta). Family 2. *Aspidochirotæ* (Stichopus, Holothuria, Aspidochir).

TABULAR VIEW OF THE CLASSES AND ORDERS OF ECHINODERMATA.



Laboratory Work.—The Holothurians are easily dissected by cutting the body open longitudinally, and pinning the specimen down in a dissecting-pan, with wax on the bottom for holding the pins. The calcareous plates can be extracted from the body-walls by being placed in a solution of potash and mounted in balsam as microscopic objects.

Encrinus or Stone Lily.

CHAPTER V.

BRANCH V.—VERMES (WORMS).

General Characters of Worms.—Having studied the one-celled animals, or Protozoans, and the radiated animals, or Cœlenterates and Echinoderms, we pass to an assemblage of forms which even in the simplest types are seen to have a dorsal and ventral, a right and left side, and a head and tail end. It is rare that the form of a worm is so modified by its habits or surroundings but that we are able to call it a worm, though when we attempt to draw up a definition of the branch or sub-kingdom *Vermes*, one which shall exclude the worm-like Holothurians or the Mollusks, or certain low mites and crustacea, or even the *Amphioxus*, we find it impossible to lay down a set of characters which shall accurately and concisely define them. This is due to the fact that the worms are *par excellence* a generalized, synthetic type, from which the other branches of the animal kingdom above the Protozoa and sponges have probably originated. It will be well for the student not to trouble himself at first about a definition of the branch, but to study with care the leading types, and then, in a review of the group, he will have a more or less definite idea of the sub-kingdom, and perceive where its borders, here and there, merge into other branches, and he will be then able to understand the grounds for the speculations regarding the phylogeny or ancestry of the other branches, which have all an apparent starting-point from low or simple forms resembling such worms as we are next to describe.

As a provisional definition of a typical worm, we may say that it is a many-celled, three-germ-layered, bilateral animal, with a well-marked dorsal and ventral side and a head and tail end, with the body in the higher forms divided at regular intervals into segments (somites or arthromeres), with usually a definite relation of the more important viscera to the body-walls—*i.e.*, a digestive tract extending from the head to the end of the body, the nervous system consisting of a brain, or supraœsophageal ganglion, and a single or, more commonly, double chain of ganglia, resting on the floor of the body ; a dorsal vessel or heart is usually present being situated above the digestive tract. True jointed appendages are never present, and in the embryo the blastoderm is usually without any "primitive streak" (the *Annulata* excepted). This definition will exclude the worm-like *Actinozoa* and Holothurians.

Before describing the lowest class of worms, we may call attention to a small aberrant group called *Mesozoa* by E. Van Beneden, the position of which is doubtful, though the animals composing it are probably aberrant worms.

In 1830 Krohn observed in the liquid bathing the "spongy bodies," or venous appendages, of different species of Cephalopods certain filiform bodies, covered with vibratile cilia, and resembling *Infusoria*. They were afterward named *Dicyema* by Kölliker, who with others considered them as intestinal worms. In 1876 Professor E. Van Beneden gave a full account of their structure and mode of development. He states that these organisms have no general body-cavity, but that the body consists (1) of a large cylindrical or fusiform axial cell, which extends from the anterior extremity of the body, which is slightly enlarged into a head, to the posterior end ; (2) of a single layer of flat cells forming around the axial cell a sort of simple pavement epithelium. All these cells are placed in juxtaposition like the constituent elements of a vegetable tissue. There is no trace of a homogeneous layer, of connective tissue, of muscular fibre, of nervous elements, nor of intercellular substance. There is only between the cells a homogeneous substance, such as is found between epithelial cells. The axial cell is regarded as homologous with the endoderm of the higher animals (*Metazoa*). Van Beneden designates as the ectodermic layer the cells surrounding the large, single axial cell. There exists no trace of a middle layer of cells, nor of any organs, all the animal and vegetative functions being accomplished by the activity of the ectodermic cells and of the single axial cell. There is no mesodermic cell or cells. On account of these characteristics, Van Beneden regards these organisms as forming the type of a new branch of the animal kingdom, which he distinguishes as *Mesozoa.* He places the branch, or sub-kingdom, between the *Protozoa* and all the many-celled animals (*Metazoa*), and includes the hypothetical *Gastræades* of Haeckel in the branch. While this position may prove to be the correct one, we should prefer, while not overlooking the resemblance of the *Dicyemidæ* to the Infusoria, and even the Gregarinæ, to wait for more light on the development of the parasitic Platyhelminth worms. It is not improbable, on the one hand, that the *Dicyemidæ*, retaining their parasitic life, are retrograde forms, which have originated from some low Cestoid or Nematoid worm, and bear the same relation to them, the

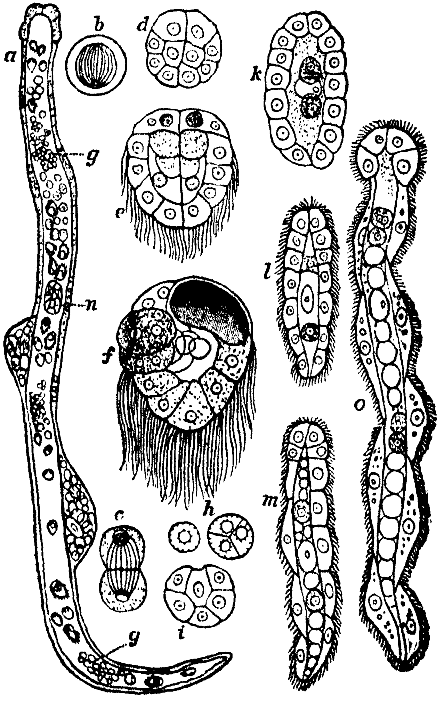


Fig. 92.—*a, Dicyemella Wagneri*; *g, g,* germigenes; *n,* nucleus of the axial cell; *b,* the spherical germ of *Dicyemella,* with its striated nucleus; *c,* the same beginning to undergo self-division; *d,* final stages of self-division (morula); *e* and *f,* infusoriform embryo; *h,* germs of the vermiform embryos of *Dicyema typus*; *i,* gastrula of the same; *k, l, m, o,* different stages of vermiform [illegible] of *Dicyema typus,* all highly magnified.—After E. Beneden.

Cestoids especially, which have no body-cavity, as the Tardigrades or *Linguatulæ* do to the higher *Arachnida.*

Each species of *Dicyema* and *Dicyemella* (Fig. 92) comprises two sorts of individuals, differing externally, one (the *Nematogene*) producing vermiform embryos, the other (*Rhombogene*) infusoriform (but many-celled) young. The Nematogenes produce germs which undergo total segmentation, and assume a *gastrula* condition. After the closure of the primitive opening, the body elongates, and the worm-like form of the adult is finally attained, when it passes through the body-walls of the parent.

The germs of the Rhombogenes arise endogenously in special cells lodged in the axial cell, and called "germigenes." The germ-like cells undergo segmentation, and then form small spheres, which become infusoriform embryos. The worm-like young is destined to be developed and live in the Cephalopod where it has been born, while the infusorian-like young probably performs the office of disseminating the species. It is possible that in those animals, such as the Cetacea, which feed on cuttlefishes, these worms (the Nematogenes at least) may pass into a genuine vermian form.

CLASS I.—PLATYHELMINTHES (*Flat-worms, Tape-worms, Fluke-worms, etc.*)

Order 1. *Turbellaria.*—In any pond of standing water one can find on the under side of sticks or stones, small dark flat worms. These are Planarian worms. The common dark-brown, almost black *Planaria torva* Müller (Fig. 93) is about six or eight millimetres long, oblong, flat, with two black eye-spots, with an oblong oval space in front of each eye. A form allied to this is a perfectly white Planarian called *Dendrocœlum lacteum* Oersted, which lives under

Fig. 93. *Planaria torva.*

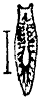


Fig. 94. *Dendrocœlum percæcum.*

submerged stones, sticks, and leaves in ponds. The body is partly transparent, with a dark area representing the stomach, from which branch out at right angles a multitude of cœcal canals (gastric cœca). It has two small black eye-specks. Closely allied to this flat worm is an eyeless form inhabiting the streams of the Mammoth and adjoining caves, which may be called *Dendrocœlum percœcum* (Fig. 94).

The foregoing forms are easily obtained by the student, who can study their habits in confinement. They all belong to the order *Turbellaria*, which is characterized by the flat, oval body, covered with cilia. The ciliary motion can be detected, as Moseley has done, by placing a little arrowroot meal or fine bits of paper on the back of the animal; these were seen to move in a forward direction on the anterior part of the body of *Geoplana flava* Moseley, a Brazilian land-planarian, and posteriorly they moved backward. "In all regions of the dorsal surface it moved outward, as was observed by Fritz Müller, at the same time as backward or forward, and was thus rapidly thrown off at the side of the body, the dorsal cilia apparently subserving especially this function of the speedy removal of foreign substances from the surface of the body" (Moseley). The structure of the flat worms may be understood by referring to Fig. 95, which illustrates the anatomy of a common European marine flat-worm. The digestive canal opens by a mouth situated usually behind the middle of the body, which leads into a chamber containing a cylindrical or funnel-shaped proboscis, capable of being suddenly thrust out. The digestive canal is either a short blind sac, or is long, forked, and either simple or much branched (Fig. 95, *e*).

These worms have a so-called water-vascular system, consisting of two lateral canals and numerous branching lateral stems, with a common opening or pore in the skin between the two main stems, or there may be many pores. The vessels are ciliated within, and are supposed to have a respiratory or excretory function. The nervous system consists of a double ganglion situated on the front end of the body (Fig. 95, *f*), from which nerves pass in different directions, but a true nerve-cord is not known with certainty to exist.* The eyes are very simple, indicated by two or more, sometimes thirty, dark pigment spots. In certain forms, such as *Macrostomum*, there is a rudimentary ear (otocyst).

Most of the Planarians, land and aquatic, have organs of defence in the form of minute, stiff rods, either coiled up in an irregularly spiral manner, or short and straight, contained in oval cells. These bodies are shot out in great numbers when the animals are irritated, but are not retractile, being projected clear from the skin. In being neither retractile nor barbed, they differ from the lasso-cells of the jellyfishes. That, however, they are true urticating organs has been proved by Mr. Thwaites (at the suggestion of Mr. Moseley), who, on touching certain Ceylonese land-planarians with his tongue, felt an unpleasant tingling or scalding sensation, accompanied by a slight swelling.

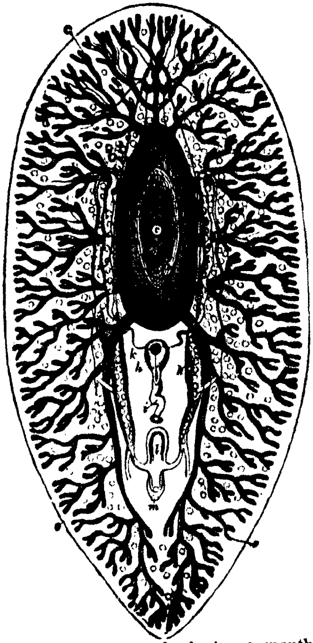


Fig. 95.—*Polycelis lævigata.* *a*, mouth; *b*, buccal cavity; *c*, œsophageal orifice; *d*, stomach; *e*, branches of the stomach; *f*, ganglia; *g*, testes; *h*, vesiculæ seminales; *i*, male genital-canal; *k*, oviducts; *l*, sperm-sac; *m*, opening into the oviduct.—After Quatrefages.

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* Schmarda describes the nervous system of *Bipalium dendrophilus* as formed of two pairs of ganglia, from the hinder of which arise two parallel nerve-threads, which dilate into at least nine swellings. Moseley discovered no more than one pair of ganglia in the species of *Bipalium* he examined. Blanchard has demonstrated "successive ganglionic repetitions along the nervous-threads at the right and left sides of the mid-line of the body of a large Planarian (*Polycladus Gayi* Blanch.)."—Clark's "Mind in Nature," p. 253.

The *Turbellaria* are hermaphroditic, the ovaries and testes with the accessory apparatus (Fig. 95) being present in the same individual; but in many forms the sexes are distinct.

Little is known of the development of the flat-worms. In a common marine Planarian, *Stylochus elliptica* (Girard), which is about two centimetres long, and lives under stones between tide-marks, north of Cape Cod, the eggs are deposited in May and June, in a thin, viscid band, on stones and sea-weeds. The eggs undergo total segmentation in four or five days after they are laid. The larva is round, ciliated, with a caudal flagellum. In eight or ten days after the larva has hatched, it stops swimming about, and becomes a "mummy-like body," which Girard calls a "chrysalis." In this state it floats about in the water. Its further history is unknown.

In *Leptoplana* (*Polycelis*), according to Keferstein, the yolk undergoes total segmentation as in *Stylochus*; the outer layer of cells forms a blastoderm which surrounds the more slowly growing cells within. Keferstein describes and figures the various stages by which the spherical ciliated embryo attains the form of the adult, whose development seems to be less in the nature of a metamorphosis than that of *Stylochus*.

Fig. 96.—*Catenula quaterna* undergoing self-division. —After Schmarda.

The Planarians also in some species multiply by fission, and when cut into pieces, according to H. J. Clark, each piece may eventually become a well-formed Planarian. Clark figures in his "Mind in Nature" two Planarians derived from two sections of *Dendrocœlum lacteum*, which became fully developed within eleven days after the operation. Several Turbellarians are known to undergo spontaneous fission.

Catenula lemnæ Dugès, by transverse division, forms chain-like aggregations, and a South African species, *C. quaterna*, of Schmarda, has been found by him to have the same habit. Fig. 96 represents two individuals (much enlarged) in partial division, and a chain of four individuals, natural size. The same process of strobilation has been carefully observed by Graff in *Microstomum lineare* Oersted. In the chain of four individuals (Fig. 97) I indicates the division of the first order, and II those of the second order; at the points in the zooids marked III there are indications of a future third subdivision, and at IV of a fourth; so that potentially the chain consists of sixteen zooids, and the division is first indicated in the digestive tract which forms subdivisions with septa reaching to the body-walls, while secondary and tertiary mouth-germs appear in the division-sections (m', m'', Fig. 97).

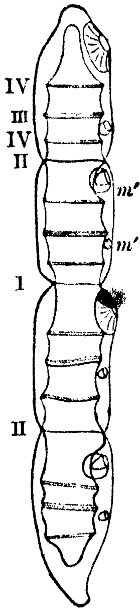

Fig. 97.—Strobilation or self-division in *Microstomum lineare*.—After Graff.

Huxley in his Manual of the Anatomy of Invertebrated Animals states that in some genera of Turbellarian worms "a difference is observed between the eggs produced in summer, which have a soft vitelline membrane, and those produced later. These so-called *winter ova* have hard shells.

The genuine flat-worms are divided into two suborders: *Rhabdocœla* and *Dendrocœla*. In the former group there is an extensible pharynx, and the digestive tract is not branched. The Rhabdocœla are represented by *Catenula, Prostomum, Microstomum*, etc.

The *Dendrocœla* sometimes have two tentacle-like continuations of the front end of the body. The digestive canal has one anterior, two posterior large, and many secondary branches, and a proboscis. Here belong the Planarians of fresh and salt water, and the *Geoplanidæ* or land-planarians, represented in the United States by *Rhyncodesmus sylvaticus* Leidy. The only parasitic species of the order known are Stimpson's *Cryptocœlum opacum*, which infests the sand-cake (*Echinarachnius parma*), and *Typhlocolax acuminata*, which lives on a Holothurian (Chirodota); while Semper has described *Anoplodium Schneideri*, which lives in the intestines of *Stichopus* *variegatum* and *Müllería lecanora,* two East Indian Holothurians.

The Planarian worms merit careful consideration, as it is possible that the Mollusca have originated from primitive forms resembling them.

Order 2. Trematodes.—Having studied the Planarians, we shall be able to appreciate the characteristics of the Trematode worms, which are all parasitic, and are constructed *on the dendrocœlous planarian type, more or less modified by their parasitic life, some being external, but most of them internal parasites.* They closely agree with the *Turbellaria* in form, never being segmented. The mouth-opening is usually situated near the fore-end of the body (sometimes in the centre), leading by a muscular pharynx to the digestive canal, which is forked and ends in two cœca. Unicellular glands open into the pharynx. In one genus (*Amphilina*) there is no digestive canal.

The Trematodes usually possess what the Turbellarians do not have, a sucking-disk (Fig. 98, *B*, *s*), situated a little behind the middle of the body, by which they adhere to the walls of the organ of the host they inhabit. The so-called water-vascular* or excretory system forms a network of vessels branching from two main lateral tubes, which unite to form a contractile vesicle ending in a terminal pore, or the main branches may end in two or more lateral pores.

The fact that there is no anal opening seems to confirm the idea that the water-vascular system is excretory, thus affording the only outlet for the waste products of digestion. There are no blood-vessels or respiratory organs, and the surface of the body is not ciliated except in the embryo. The nervous system is usually represented by a single ganglion, like that of the Turbellarians. Eye-spots are sometimes present in the young, which, with other points in their organization, tends to show that the Trematodes have originated from Turbellaria, having been modified by their parasitic life, and with somewhat the same relations to Turbellarians as Lernæan parasites have to the normal *Copepoda,* or water-fleas.

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* That the so-called water-vascular system is mainly at least excretory in its function seems proved by the fact that the fluid is watery and contains granular concretions, thus resembling the urinary excretions of the higher animals.

There is always one sucker which *usually encircles the* mouth, the other (ventral) sucker varies in position, and sometimes there is, as in the externally parasitic *Polystomidæ* (*Aspidogaster, Polystomum,* etc.), a sucker on each side of the mouth-opening. In some forms there are two large chitinous hooks in the median line between the hinder suckers, of which there may be several.

The reproductive glands are more or less complicated, and are much as in the Turbellarians. The eggs are formed (as in Cestodes, Turbellarians, and Rotifers) by two distinct glands, a *germigene* and a *vitellogene,* the latter forming the nutritive mass which envelops the protoplasmic germ or egg proper, the entire mass being afterward enveloped by the egg-shell. Frequently two or more eggs are enclosed in one shell. The species are mostly monœcious, the external opening of the oviduct and the large intromittant organ being contiguous.

The development of the egg begins by subdivision of the nucleus ; the nucleolus then divides, and subsequently the protoplasmic mass. The yolk, however, remains entirely independent of this division, and serves as nourishment for the other cells forming the body of the embryo. From E. Van Beneden's observations it appears that the eggs of the lower flukes, as a rule, undergo total segmentation, and the young of the *Distomeæ* are hatched in an oval ciliated "trochosphere" form, without eye-specks, as in *Distoma* and *Amphistoma ;* or, as in the *Polystomeæ,* there is no metamorphosis, but development is direct, the embryo passing directly into the adult condition.

It was not known before the publication of Steenstrup's work in 1842 that certain worms called *Cercariæ* were the free larval forms of the Distomes. The *Cercaria echinata,* first described by Siebold, is like a *Distomum,* except that the body is prolonged into a long extensible tail. This tail, says Steenstrup, is formed of several membranes or tubes placed one within the other, of which the outermost is a very transparent epidermis, under which is a tolerably thick membrane furnished with transverse muscular fibres, while between each pair of these transverse fibres is placed a globular vesicle which appears to be a mucous follicle or gland; the innermost tube is opaque and of firmer consistence; it contains the longitudinal muscular fibres, and is usually reticulated on the surface. Through the centre of these tubes there passes a slightly narrower canal, which becomes very small toward the extremity of the tail. The existence of the same layers in the body itself of the Cercaria can easily be demonstrated; but the transversely striated layer is here not so much developed.

Steenstrup states that these Echinate Cercariæ (Fig. 98)

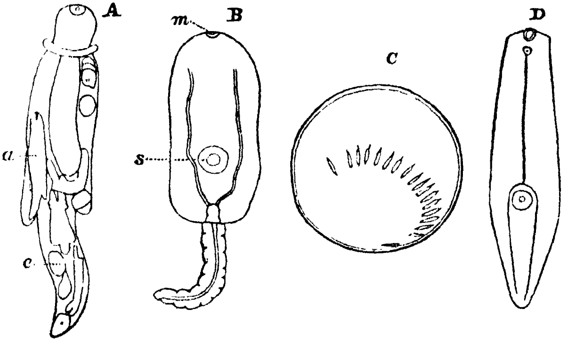

Fig. 98.—Metamorphosis of a Cercaria into a Distomum. *A*, parent nurse; *e*, germs; *a*, nurse. *B*, larva. *C*, encysted, pupal Cercaria. *D*, adult Distomum.—After Steenstrup.

are found by thousands, and frequently by millions, in the water in which two of the largest European fresh-water snails, *Planorbis cornea* and *Limnæus stagnalis*, have been kept. After swimming about in the water some time, they fix themselves by means of their suckers (*B*, *s*) to the slimy skin of the snails, in such numbers that the latter look as if covered with bits of wool.

The Cercaria, by contractions of its body and violent lashing of the tail, forces its way into the body of its host, loses its tail, and then resembles a mature Distoma. By turning about in its place and secreting a slime, a cyst is gradually formed, with a spherical shell. This constitutes the "*pupa*" state of the Cercaria. Steenstrup thinks that the Cercaria casts a thin skin. In this state the body can be seen through the shell of the cyst, as in Fig. 98, *C*, where the circle of spines embedded around the mouth is seen. The encysted Cercariæ remain in this state from July and August until the following spring; and during the winter months, in snails kept in warm rooms, they change into Distomas (Fig. 98, *D*), the mature fluke differing, however, in some important respects from the tailless larvæ. In nature they remain from two to nine months in the encysted state.

"Now," asks Steenstrup, "whence come the Cercariæ?" Bojanus states that he saw this species swarming out from the "king's yellow worms," which are about two lines long and occur in great numbers in the interior of snails. From these are developed the larval Distomes, and Steenstrup calls them the "nurses" of the Cercariæ and Distomes. They exactly resemble the "parent-nurses" (Fig. 98, *A*, and 100), and, like them, the cavity of the body is filled with young, which develop from egg-like balls of cells. Steenstrup was forced to conclude that these nurses originated from the first nurses (Fig. 98), which he therefore calls "parent-nurses." Here the direct observations of Steenstrup on the *Cercaria echinata* came to an end, but he believed that the parent-nurses came from eggs. The link in the cycle of generations he supplied from the observations of Siebold, who saw a Cercaria-like young (Fig. 99, *B*) expelled from the body of the ciliated larva of *Monostomum mutabile*. Steenstrup remarks that "the first form of this embryo is not unlike that of the common ciliated progeny of the Trematoda, as they have been known to us in many species for a long time, and it might at first sight be taken for one of the polygastric infusoria of Ehrenberg, which also move by cilia; whilst in

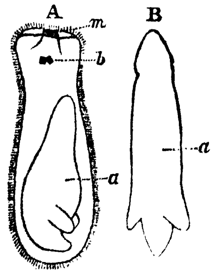

Fig. 99.—Development of *Monostomum*. *A*, ciliated larva; *m*, mouth; *b*, eyes; *a*, nurse. *B*. nurse.—After Siebold.

the next form which it assumes the young Monostomum bears an undeniable resemblance to those animals which I have termed ‘nurses’ and ‘parent-nurses’ in that species of the Trematoda which is developed from the *Cercaria echinata.*”

Thus the cycle is completed, and the following summary of changes undergone by the Distomes present as clear a case of an alternation of generations as seen in the jelly-fishes:

1. Egg.
2. Morula.
3. Ciliated larva.
4. Redia (parent-nurse, *Proscolex*) producing
5. Cercaria (nurse, *Scolex*).
6. Encysted Cercaria (*Proglottis*).
7. Distomum (*Proglottis*).

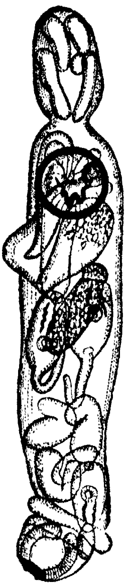

Fig. 100.—Proscolex or parent-nurse of *Distomum echinatum* filled with cercariæ.—From Gervais and Beneden.

The *Distomum echinatum* (Fig. 100), living in snails which are eaten by ducks, have been shown by St. George to develop into the adult Distoma in the body of that bird. It is generally the case that those Distomes which pass through an alternation of generations live in the larval state in animals which serve as food for higher orders. Thus the Bucephalus of the European oyster passes in the encysted state into a fish which serves as food for a larger fish, *Belone vulgaris,* in whose intestine the adult of the same worm, a species of *Gasterostomum,* occurs. The American oyster is infested by *Bucephalus cuculus* Macrady. It infests the ovary of the oyster. Whether it is permanently injurious to the latter is unknown.

Fasciola hepatica (Fig. 101), the liver-fluke, sometimes occurring in man, is thought by Dr. Willemoes-Suhm to begin its existence as *Cercaria cystophora,* parasitic on a species of Planorbis.

It is most abundant in sheep in the spring, several hundred occurring in the liver of a single sheep. At this time it passes into the intestine, and thence is carried out with the excrement. The eggs or flukes in many cases drop into pools, ditches, or ponds ; here the ciliated young (like Fig. 99) is liberated, and soon the ciliæ are absorbed, when it becomes inert, and probably soon afterward enters the body of a snail (*Planorbis*, etc.), where it transforms into a large sac, and develops new larvæ in its interior. This sac-like larva is called a "nurse," "sporocyst," or, when more highly developed, a "*redia.*" The progeny of the *redia* is termed a "cercaria." The cercariæ are restless, migrating from the bodies of their snail-host, and have been known in a few instances to penetrate the skin of human beings. They are probably more usually swallowed by sheep and cattle while drinking or grazing, when snail-shells may be accidentally swallowed. From the digestive canal of sheep, etc., the *cercaria* penetrates into the liver, where it probably loses its tail and becomes encysted, after many weeks or even months becoming a sexually mature distome. From the liver it passes out through the liver-ducts into the intestine, and is finally expelled, thus completing its cycle of life (Cobbold).

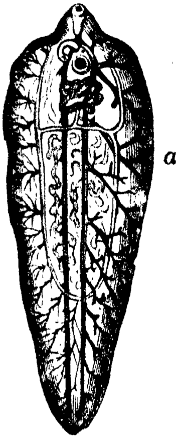

Fig. 101.—*Fasciola hepatica*, enlarged. *a*, branched intestine.—From Gervais and Van Beneden.

Distomum lanceolatum Mehlis differs from *Fasciola hepatica* in the intestine being simple and forked, while that of the latter is much branched. It has occurred but three times in man, but is not rare in the sheep and ox. It has been detected in Europe in the pig, deer, rabbit, and hare. Two immature Distomes have been found in the human eye, and Cobbold thinks they may both be the young of *D. lanceolatum.* It is described by Diesing under the name of *Distomum ophthalmobium,* is half a line in length, and occurred between the lens and its capsule, appearing as dark spots on the surface of the lens. *Distomum crassum* Busk and *D. heterophyes* Siebold have each been only once found in man, the former in a Lascar, the latter in an Egyptian boy.

Bilharzia hæmatobia Cobbold is common in the portal system of blood-vessels and in the veins of the mesentery, bladder, etc., of Egyptians, and has caused an endemic disease at the Cape of Good Hope. In Egypt, out of three hundred and sixty-three *post-mortem* examinations, this worm occurred one hundred and seventeen times. It is bisexual, the female greatly smaller than the male, living in a canal or passage in the male formed by the infolding of the edges of the concave side of the body, called a *gynæcophore.* There are three other rare human flukes known: *Tetrastoma renale* Delle Chiaje, *Hexathyridium pinguicola* Treutler, and *H. venarum* Treutler, the latter occurring in the veins (Cobbold).

The nurse of *Distomum macrostomum* Rudolphi (Fig. 102), described under the name of *Leucochloridium,* is cylindrical, and strongly resembles a maggot; its strange habitat is the tentacles of a snail (*Succinea*).

Of the second suborder, *Polystomeæ,* the species have two small anterior and one or several posterior suckers, and a pair of eyes. They are mostly external parasites, like the leeches, and undergo no metamorphosis. In some forms the body is segmented.

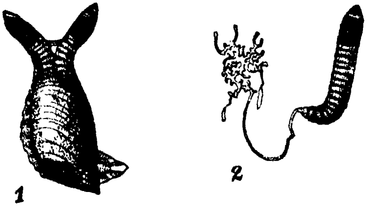

Fig. 102.—1. *Leucochloridium paradoxum,* living in the tentacles of Succinea; 2 A full-grown nurse-Leucochloridium with the nurse-stock from which it has grown. Natural size. After Zeller

A type of this suborder is *Aspidogaster conchicola* Baer, which inhabits the pericardial cavity of fresh-water mussels, and also is an ectoparasite of fresh-water fishes. *Diplozoon* consists of two Trematodes very intimately united into an X-formed double animal. In the young stages the two animals are separate, and in this state were described under the name of *Diporpa. Diplozoon paradoxum* Nordmann lives on the gills of numerous fresh-water fishes. *Polystomum* has a flat body, without suckers on the fore end, with six suckers and two large median ventral hooks on the hinder end. The ripe eggs are deposited in the water in winter, when the ciliated young, with four eyes and without suckers, find their way into the gill-cavities of tadpoles, whence, during or after metamorphosis, they pass into the urinary bladder of young frogs; *P. integerrimum* Rudolphi lives in that of *Rana temporaria* (Claus' Zoologie).

A case of budding or parthenogenesis is said to occur in the genus *Gyrodactylus.* This is a very small Trematode with a large terminal disk, bearing a peripheral set of powerful hooks, with two long curved median spines. The body of the hermaphrodite worm shelters a daughter, a granddaughter, and great-granddaughter generation. *G. elegans* Nordmann lives on the gills of Cyprinoid and other fresh-water fishes. *Dactylogyrus* lays eggs, not being parthenogenetic; it has four head-flaps. *D. amphibothrium* Wagener lives on the gills of the stone-perch; *D. fallax* Wagener on *Cyprinus rutilus.*

Order 3. *Cestodes.*—The common tape-worm is the type of this order. Specimens may be procured from physicians, and a careful examination of cross-sections and ordinary dissections will convince the student that the tape-worm has no mouth, although a head armed with suckers or hooks. The body is divided into an enormous number of segments or proglottids, but there is no digestive canal, the worm living immersed in the contents of the intestines of its host; its food being absorbed from the juices of its host through the walls of the body.

The tape-worms and their allies are not known with certainty to have any trace of a nervous system. The water-vascular system is well developed in the Cestodes, where it seems to be excretory in its functions, as in the Trematodes. There are usually four, sometimes only two, longitudinal canals, which are connected in the head and in each segment with transverse anastomosing branches, while from these main canals a network of fine vessels branch out. Granules and whitish chalky deposits occur in the canals, and these concretions, like similar bodies in the excretory canals of Trematodes, seem to have, Leuckart claims, a relation like that of the crystals of oxalate of lime in the urinary tubes of many insects and the concretions of phosphate of lime in the organ of Bojanus of Lamellibranch mollusks.* The canals terminate in a small pulsating vesicle and pore, as in the Trematodes.

The Cestodes are hermaphroditic, and each of the body-segments except those nearest the head contains male and female reproductive organs. The male parts consist, as in the Trematodes, of testes, *vasa deferentia*, and a muscular sac with a cirrus or intromittent organ, which may penetrate the vagina of the same segment. The female organs consist of an ovary (germigene), yolk-stock (vitellogene), uterus or matrix, *receptaculum seminis*, and vagina, the latter opening by a pore situated in *Tænia* (Fig. 107) on the side, or in *Bothriocephalus* on the ventral surface of the segment. There is a great deal of variation in the reproductive organs of the tape-worms; a general idea of the relations of parts may be obtained by reference to Figs. 107 and 109. The ovary forms the most important part. It is much developed and very complicated in structure. As Gegenbaur states: "The preservation of the species is here subject to innumerable difficulties, owing to the animal living in different hosts at different stages of development, and to the wanderings which this mode of life entails; consequently a large number of ova have to be produced, and the certainty of fecundation insured." (Elements of Comparative Anatomy, second edition, English translation.) The male organs and products are first developed, and the *receptaculum seminis* stored with spermatic cells before the eggs fully develop in the ovary, and all these parts develop earliest in the terminal segments of the body destined to form the *proglottides*.

Development begins very probably, as in the *Trematodes*, through multiplication by division of the nucleus (germinative cell). In the eggs of *Tænia bacillaris* E. Van Beneden

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* This is Leuckart's opinion. Sommer and Landois claim that these bodies are scattered through the substance of the body, and do not occur in water-vessels. Huxley endorses this view. But if these bodies are concretions and the water-vessels are mainly excretory, as they certainly appear to be, we should judge that Leuckart's view was the better grounded.

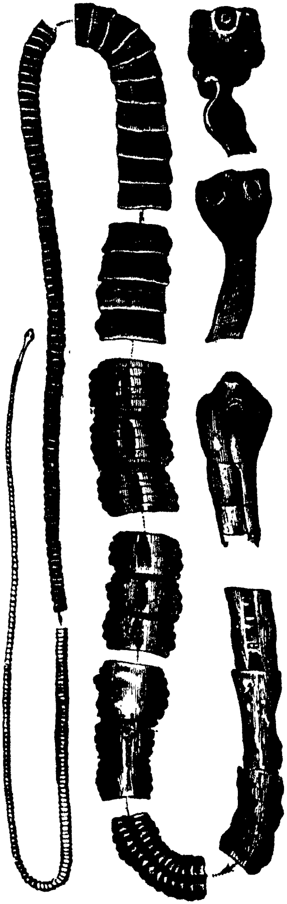


Fig. 103.—*Tænia solium*. Nat. size, with the head magnified. Strobila stage. —After Beneden.

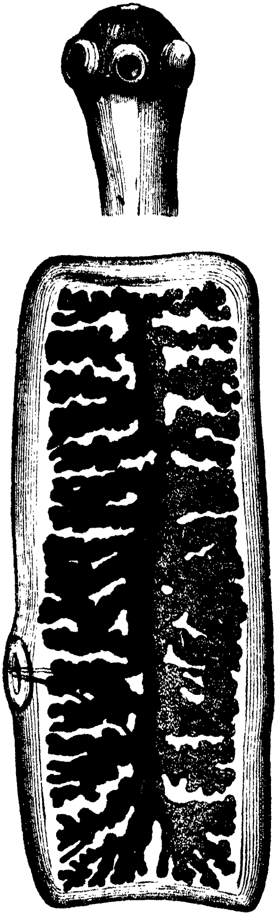


Fig. 104.—Head and proglottis of *T. solium*.—After Beneden.

saw the nucleus subdivide; after passing through a *morula* condition the cells are arranged in two layers, and the outer layer is thrown off (this probably corresponding to the serous membrane of insects and crustacea); the central mass (which is not hollow as in the *gastrula* of other worms, a digestive cavity not being present in after life) forms the embryo, and soon three pairs of hooks arise. Three structureless membranes are secreted around the embryo, which then hatches. The embryo of Bothriocephalus is provided with a ciliated membrane, which corresponds to the first blastodermic moult of the embryo Tænia, which, on the other hand, is not ciliated.

The history of the human tape-worm, *Tænia solium* (Fig. 103) is as follows: the eggs eaten by the hog are developed in its body into the larval tapeworm (scolex), called in this species *Cysticercus cellulosæ* (Fig. 105; Fig. 106, head enlarged). The head with its suckers is formed, and the body becomes flask-shaped; the Cysticerci then bury themselves in the liver or the flesh of pork, and are transferred living in uncooked pork to the alimentary canal of man. The body now elongates and new joints arise behind the head until the form of the tapeworm is attained, as in Fig. 103.

The hinder joints then become filled with eggs and break off, becoming independent zooids comparable with the "parent-nurses" of the Cercarias, except that they are not contained in the body of the Tænia (as in the Cercaria), but are set free. The independent joint (Figs. 104, 107) is called a "proglottis." It escapes from the alimentary tract of its human host, and the eggs set free, in and about privies, are swallowed by that unclean animal, the pig, and the cycle of generations begins anew. We thus have the following series of changes, which may be compared with the homologous series in the flukes:

1. Egg.
2. Morula.
3. Double-walled sac (gastrula?).
4. Proscolex, free embryo with hooks, surrounded by a blastodermic skin.
5. Scolex (Cysticercus, larva). Body few-jointed.
6. Strobila (Tænia). Body many-jointed.
7. Proglottis (adult).

The common human tape-worm, *Tænia solium* Linn., varies from ten to thirty feet in length ; there are upward of eight hundred joints in a worm ten feet long. The head ends in a rostellum or proboscis armed with a double crown of hooks ; the first proglottis or sexually mature segment begins at the 450th. While in some persons the presence of a tape-worm is simply an annoyance, in nervous and irritable persons it causes restlessness, undue anxiety, and various dyspeptic symptoms. In rare cases (over a hundred are known) death has resulted from the presence of the Cysticercus in the brain. "Cysticerci may develop themselves in almost any situation in the human body, but they occur most frequently in the subcutaneous, areolar, and intermuscular connective tissue ; next, most commonly in the brain and eye ; and, lastly, in the substance of the heart and other viscera of the trunk" (Cobbold). Among the preventive remedies against tape-worms is the disuse of raw or underdone pork, and "measly" pork—*i.e.*, the flesh of swine containing the little bladder-like vesicles. Cysticerci, or larval tape-worms, can be readily distinguished, but when thoroughly cooked are harmless, as the temperature of boiling water is

Fig. 105.—*Cysticercus*, or larval Tape-worm.

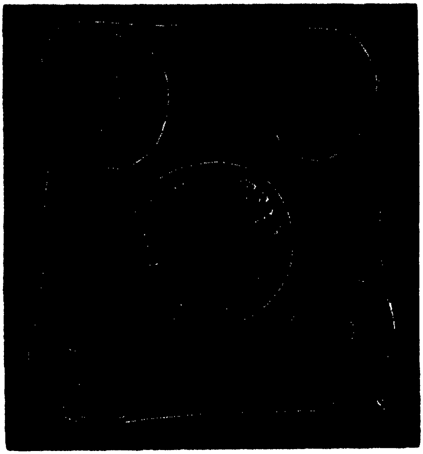


Fig. 106.—Head of *Tænia acanthotrias* (Cysticercus) enlarged, showing the suckers (*S*) and circle of hooks.

sufficient to kill the Cysticerci. Butchers especially suffer from tape-worms, from their habit of eating bits of raw meat, beef and veal harboring Cysticerci, which transform into species of *Tænia* nearly as injurious as *Tænia solium.* As a matter of course, in the use of drugs to expel a tape-worm, they should be pushed so as to carry off the entire animal, as new segments grow out from near the head as rapidly as the proglottides are detached.

The Cysticercus of another injurious tape-worm lives in the muscles and internal organs of cattle. This is the *Tænia mediocanellata* of Küchenmeister, which is larger, with a larger darker head, larger suckers, and without a rostrellum or hooks. By far the most injurious species is *Tænia echinococcus* Siebold (Fig. 108), more frequently causing death than any other entozoon. In its adult or *strobila* state this worm only infests the dog and wolf, but its larva, the hydatid of physicians, frequently occurs in the human body. It is very small, seldom exceeding six millimetres in length, there being but four segments, including the head, which has a pointed rostellum, with a double crown of large-rooted hooks ; there are four suckers present, and the last segment, when sexually mature, is as long as the anterior ones taken together. The hydatid (*proscolex*) forms large proliferous vesicles, in which the scolices (Echinococcus heads) are developed by budding internally. About five thousand eggs

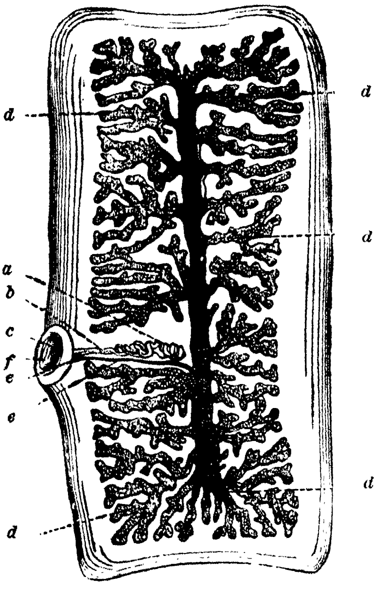


Fig. 107.—Proglottis of *T. solium.* *a*, testis ; *b*, sperm duct ; *c*, orifice of cirrus ; *d*, matrix filled with eggs ; *e*, vagina ; *f*, sexual cloaca.—After Beneden.

are developed in a single segment (*proglottis*). The six-hooked embryos develop, are expelled from the dog, and find their way in drinking-water or in food into the human intestines, whence they bore into the liver, their favorite habitat, or are carried along the blood-vessels into some other organ, where they develop into bladder-like bodies called acephalocysts or hydatids. In its earliest stages the hydatid is spherical and surrounded by a capsule of condensed connective tissue of its host. By the fourth week the young *T. echinococcus* is one half a millimetre (one-fiftieth inch) in length, and it is probably many months before the Echinococci heads are entirely developed. When this stage is reached the tape-worms become sexually mature in from seven to nine weeks after, when the milk-white worms may usually be found embedded in the mucus of the duodenum and upper part of the small intestines, with their heads attached to the villous surface of the intestine. The hydatids or cysts in which the Echinococci develop are of three kinds—viz., exogenous, endogenous, and multilocular, and lie embedded in the parenchym of the liver, etc., and are filled with a clear amber-colored fluid. The Echinococcus heads, first on the inner surface of the cyst and in the interior of the Echinococcus-head (brood-capsule), develops a second brood of scolices, contained in a secondary cyst. Finally, a tertiary cyst, containing tertiary or granddaughter scolices, arises. Sometimes the secondary hydatids will develop scolices and granddaughter vesicles before the original maternal hydatid has acquired Echinococcus heads (Cobbold).

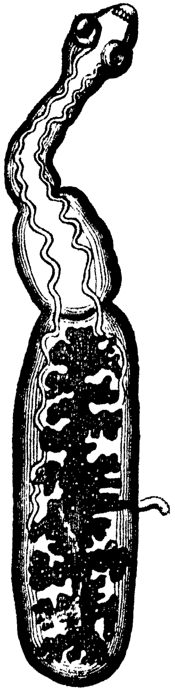
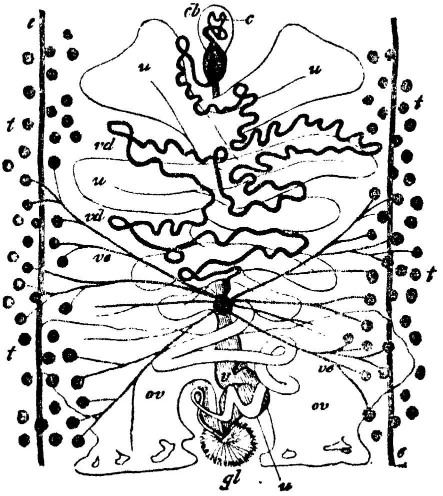


Fig. 108. — *Tænia echinococcus*. — After Beneden.

The largest human tape-worm is *Bothriocephalus latus* Bremser (Fig. 109).

This worm is extremely rare in America, but is common in Western Switzerland and Central Europe, and in the northwestern and northern provinces of Russia, Sweden, and Poland. It is sometimes twenty-five feet long, and nearly an inch broad, with 4000 joints. The club-shaped head is unarmed, and the first sexually mature segment is about the 600th from the head. Leuckart has suggested that the young of this tape-worm originate in salmon and trout.



. 109.—Male reproductive organs, with parts of the female of *Bothriocephalus* *t*, testicular follicles, only a part are represented ; *ve*, their excretory ducts ; *vd*, vas deferens ; *c*, cirrus ; *cb*, sac containing the cirrus ; *u*, uterus containing eggs ; *ov*, ovary ; *gl*, shell-gland ; *e*, water-vascular trunks ; *v*, vaginal canal.—After Landois and Sommer ; from Gegenbaur.

The sheep-hydatid is the larva of *Tænia cœnurus* (Figs. 110 and 111), the adult infesting the dog. The presence of one or several of the hydatids in the brain of the sheep produces the "staggers" or vertigo. The vesicle varies in size from a pea to a pigeon's egg. It is bladder-like, filled with a clear pale yellow albuminous secretion, with a great number of retractile papillæ (*D*, *g*), which are the tape-worm heads connected by narrow stalks to the common vesicles supporting the colony. This hydatid also infests cattle, the horse, goat, various species of antelope and deer, the dromedary, and, it is said, the rabbit. "In the sheep the disease is recognized at first by a heavy, stupid, wandering gait, which is frequently succeeded by irregular, tortuous, whirling movements of the body, accompanied with convulsions (Cobbold).

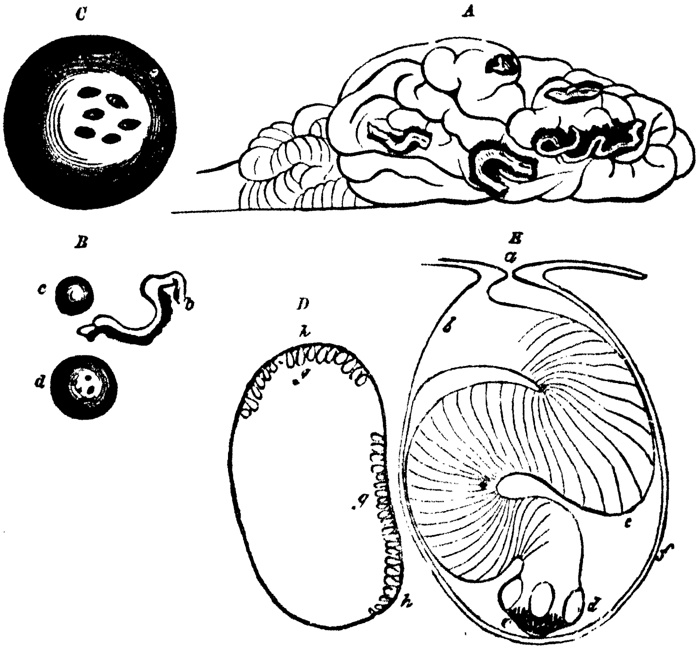


Fig. 110.—*A*, brain of a sheep which three weeks previous had swallowed some eggs of *T. cœnurus*, and which was killed after having shown all the symptoms of "staggers." *B b*, isolated gallery formed by the worm at the surface of the brain, the scolex being found at the end of the gallery. *B c*, vesicle (proscolex) before the birth of the scolex. *B d*, vesicle in which the scolices will appear. *C*, vesicles which have produced some scolices. *D*, the hydatid vesicle containing *gg*, the secondary vesicles. *E*, scolex of *T. cœnurus*, corresponding to a secondary vesicle *D g*, and very much magnified and invaginated. *a*, point at which the head of the worm will issue out; *b*, point of junction with the hydatid vesicle; *c*, hooks; *d*, the suckers; *e*, the neck; *f*, the wall of the hydatid cyst.—After Beneden.

The simplest form in the order is *Caryophyllæus*, in which the body is not jointed in the adult, though it is so in the young, and there are no suckers or hooks; while there is but a single set of male and female reproductive organs situated in the posterior end of the body, which can be detached from the anterior part of the body, forming a proglottis. In fact, this form is a connecting link between the *Trematoda* and *Cestodes*. *Caryophyllæus mutabilis* Rudolphi lives in the intestines of Cyprinoid fishes; the young in a worm, *Tubifex rivulorum.*

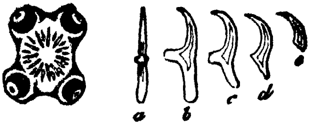


Fig. 111.—Head of *T. cœnurus* seen from above, with circle of hooks; *a—e*, hooks; all much enlarged.—After Siebold.

Tetraryhnchus is provided with four very long slender extensile spiny cephalic processes or beaks. The young live encysted in bony fishes, the adults occurring in the intestines of sharks and rays.

In *Ligula* the body is ribbon-shaped, not jointed, with a series of sexual organs, and there are no suckers, and sometimes no hooks. *L. simplicissima* Rud. lives in fishes and amphibians, and attain maturity in the intestines of water-birds, which feed on the former animals. This genus connects the simpler tape-worms with *Bothriocephalus* and *Tænia.*

Class I.—PLATYHELMINTHES.

More or less flattened worms, with the body usually unsegmented; the head in the Cestodes often armed with hooks or suckers. Simple or branched (Turbellaria) or forked (Trematoda) digestive tract, but no general body-cavity. (The digestive cavity is entirely wanting in the Cestodes.) Nervous system represented by a cephalic ganglion, which in the Cestodes is absent. A system of vessels corresponding to the water-vascular system of Echinoderms, but supposed to be mainly excretory in function. Monœcious, rarely bisexual. Ovaries differentiated into a germigene and vitellogene; often parthenogenetic, accompanied by strobilation in the tape-worms. When alternation of generations occurs by budding, the sexual animals are united with their nurse or a sexual form into a polymorphic colony.

Order 1. *Turbellaria.*—Flattened ovate worms, with a nervous ganglion in the head; usually eye-specks; body externally ciliated, with a much-branched digestive canal. Nettling organs often present. Unisexual, rarely bisexual; strobilation very rare; a metamorphosis in the *Dendrocœla*, the larva being a trochosphere. Suborder 1. *Rhabdocœla* (Monocelis, Catenula, Mesostomum). Suborder 2. *Dendrocœla* (Planaria, Dendrocœlum, Geoplana, and Bipalium).

Order 2. *Trematoda.*—Usually flat, oval, rarely cylindrical, not segmented, parasitic worms, with a mouth, forked intestine, no anus; a large sucker near the middle of the body, or several smaller ones; either with a metamorphosis (Distomeæ), the larva living in mollusks, etc., the adult in vertebrates; or with direct development (*Polystomeæ*). Suborder 1. *Distomeæ* (Monostomum, Amphilina, Distomum, Amphistomum). Suborder 2. *Polystomeæ* (Aspidogaster, Diplozoon, Polystomum, Gyrodactylus).

Order 3. *Cestodes.*—Parasitic, usually ribbon-like worms, without any mouth, digestive canal, or nervous system; with an (excretory) water-vascular system; hermaphrodite, the joints (proglottis) numerous and containing male and female reproductive organs; the eggs minute and very numerous. The mature worm is many-jointed, the joints budding out from near the head; in this form it is called a *strobila*; the terminal joints fall off, becoming independent (*proglottis*). The eggs after fertilization pass through a morula and gastrula stage, a circle of hooks and suckers developing on the head (Caryophyllæus, Tetrarhynchus, Ligula, Bothriocephalus, Tænia).

Laboratory Work.—The flat worms have been most successfully studied by fine injections, especially by slicing hardened sections, which should be stained with carmine, and mounted for the microscope.

CLASS II.—NEMATELMINTHES (*Round, Thread-worms*).

General Characters of Thread-worms.—These worms are either free or parasitic; examples of the former exist in abundance under stones, etc., between tide-marks, lying in coils; small, almost minute species occurring in fresh water and in damp earth, while the parasitic species, which are the most numerous, live free in the alimentary canal or imbedded in the flesh of their hosts, especially fishes and mammals. The species are remarkably persistent in form, the specific and generic differences being very slight. They have a mouth and digestive canal (except in *Echinorhynchus*), he integument being hard, chitinous, and not segmented except in *Desmoscolex*, which approaches in this respect the nnelids), and usually smooth, except in *Echinoderes*, which s variously armed with hair-like spines. Each end of the ody is much alike, the mouth situated at the anterior end, nd the anal opening at or near the conical tip of the body. There are two long vessels which extend from a single common pore situated on the median line of the under side of the ody, a short distance from the head; these are supposed to e excretory vessels. In *Ascaris* and *Oxyuris* a nervous ring urrounds the œsophagus, from which two nervous threads, one dorsal the other ventral, pass to the end of the body, and there are six other smaller longitudinal nerves. The ganglionic cells lie near the nervous ring, forming a subœsophageal, supraœsophageal and lateral ganglion, and there is also a caudal ganglion. In some free-living Nematodes there are eye-specks.

The Nematodes are usually bisexual; *Pelodytes* is hermaphroditic, while the same individual of *Ascaris nigrovenosa* at first produces sperm-cells and afterwards eggs. The males differ from the females in their smaller size and the usually curved end of the body. While most of these worms lay eggs, some, as in *Trichina spiralis*, bring forth their young alive.

The mode of development of these true Nematode worms (*Echinorhynchus* excepted) so far as known is quite uniform, growth being direct, without any metamorphosis. The germ is formed in three ways: (1) usually the egg undergoes total segmentation; (2) others, as in *Ascaris dentata* and *Oxyuris ambigua*, do not show any apparent trace of segmentation, while (3) in *Cucullanus elegans* there is no yolk, the nucleus absorbing all the vitelline matter, which is limpid and transparent. The germ consists of a single series or circle of cells bent on itself, somewhat as in Fig. 120, which represents a little more advanced stage in Sagitta, and there are a few cells representing the endoderm. The embryo rapidly assumes the adult form before hatching.

Order 1. *Acanthocephali.*—These are aberrant Nematode worms (sometimes referred to a separate class), without any mouth or digestive tract, but with an extensible spiny beak, living by imbibition of the fluids of the alimentary canal of their host.

The thick subcuticula is penetrated by a network of vessels, whose trunks form two oval bodies of unknown use called *lemnisci*, which hang down free in the body-cavity. The sexes of *Echinorhynchus* are distinct. The eggs are usually spindle-shaped. The embryo develops in the body of the parent worm, and is surrounded by several membranes, with a circle of hooks arranged bilaterally around the mouth. The embryo contains an oval mass of nuclei, being the rudiments of an intestinal canal. Finally it passes into some crustacean or insect, in whose body it becomes so far developed, that when its host is swallowed by some vertebrate, such as a fish, the embryo is liberated in the intestines of the second (vertebrate) host and soon attains sexual maturity. Nearly a hundred species are known.

Fig. 112.—*Echinorynchus*, head retracted and in the second figure extruded; magnified. *a*, oval pore; *b b*, protractile muscles; *c c*, lemnisci.—After Owen.

Echinorhynchus gigas, the female of which is 50⅔ centimetres (20 inches) in length, lives in the small intestine of the pig. Its eggs pass out, becoming scattered on the ground, where they are eaten by the white grub or larva of the European cockchafer. The egg-membranes burst in the stomach of the grub, and the embryos thus liberated penetrate, by female is white and from eight to ten millimetres in length; the male is only two or three millimetres long.

The largest known round worm is the palisade worm, or *Eustrongylus gigas* Rudolphi, the female of which is a metre (about 39 inches) in length, and the size of a quill; the male is one third as long. It is rare in man, and occurs especially in the intestines, and sometimes the kidneys of such mammals as live on fish. The mouth is surrounded

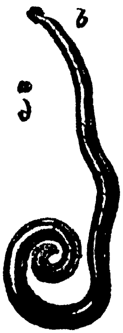


Fig. 114.—*Oxyuris vermicularis.* *a*, male, natural size; *b*, the same enlarged.—After Beneden.

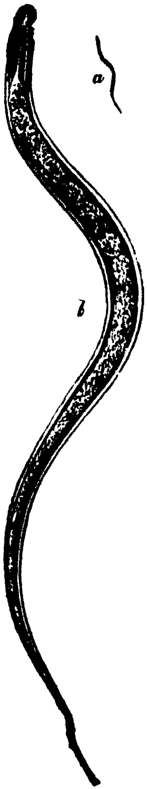


Fig. 115.—*Oxyuris vermicularis.* *a*, female, natural size; *b*, the same enlarged.—After Beneden.

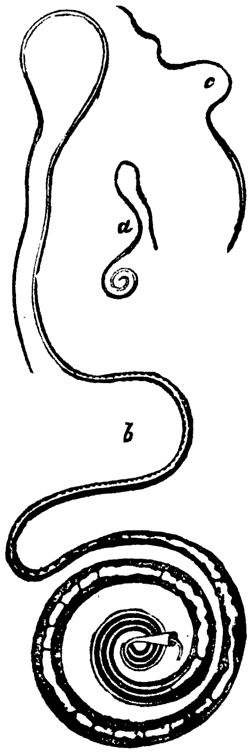


Fig. 116.—*Trichocephalus dispar.* *a*, male, natural size; *b*, enlarged; *c*, female, natural size.—After Beneden.

by six tubercles. *Eustrongylus papillosus* Diesing, according to Wyman, lives coiled up in the brain of the anhinga, or snake-bird of Florida. *E. buteonis* Packard was found living under the eyes of *Buteo Swainsoni*, and *E. chordeilis* Packard in the brain of the night-hawk. *Dochmius duodenalis* Dubini lives in the small intestine of man.

Trichocephalus dispar Rudolphi (Fig. 116) lives in the cœcum of man, with the smaller anterior part of the body buried in the mucous membrane.

The most formidable round worm is the *Trichina spiralis* Owen (Fig. 117). The body is regularly cylindrical, tapering gradually from the posterior end to the head. The end of the body of the male is without a spiculum, but with two conical terminal tubercles. It is 1.5 millimetres long. The female is 3 millimetres in length.

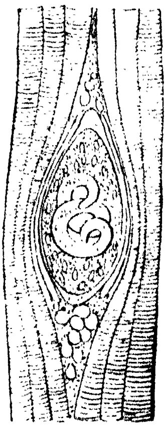


Fig. 117.—*Trichina* encysted in human muscle. Greatly magnified.—After Leuckart.

Viviparous females begin about eight days after entering the intestine of their host to give birth to the larvæ, which bore through the walls of the intestines of their host, passing into the body-cavity, and partly into the connective tissue, and also, by means of the circulation, into the muscles. In about fourteen days the worm coils up spirally in a cyst (Fig. 117), which eventually becomes calcareous and whitish. When the flesh of the pig, infested by the encysted larvæ, is eaten by man, the young worms are set free in the stomach of their new host, and in three or four days become sexually mature. The female Trichina is capable of producing a thousand young. The original host of the Trichina is the rat; dead rats are often devoured by pigs, and the use of raw or partially cooked pork as food is the means of infection in man.

Another worm, occasionally parasitic in sailors and residents of the East Indies, is the *Filaria medinensis* Gmelin, or Guinea-worm. It is remarkably long and slender, sometimes over two feet in length. The female is viviparous, while the male is unknown. The worm lives in the connective tissue under the skin, especially of the extremities. As the body of the female is full of young, the worm has to be carefully and slowly extricated, so as not to be broken and cause the embryos to be scattered under the skin of the host. Carter regards a small worm (*Urolabes palustris*) frequent in brackish water, as the immature form of the Guinea-worm. It is also believed that the embryos enter the bodies of water-fleas (Cyclops, etc.), and there moult, and that consequently they may be introduced into the body by drinking standing water; but this has not been proved. Other species live in the peritoneum of the horse and apes, and an immature species (*Filaria lentis*) has been found in the lens of the human eye. *Filaria sanguinis-hominis* is a worm of microscopic size found living in the blood of the mosquito in India and China. It is said that the eggs are swallowed in the water drunk by man, are hatched in his intestines, and obstruct the smaller blood-vessels, causing, it is claimed, various forms of elephantoid disease, perhaps even leprosy. The mosquito sucks up the parasite in the blood of leprous patients, voiding the eggs in the pools it frequents. *Filaria hematica* has occurred in the blood of the fœtus of a dog whose heart was filled with them. Ears of wheat are often infested by a minute Nematode (*Tylenchus scandens* Schneider, *Anguillula tritici* of Needham, Fig. 118). Other species live in flowers, moist earth, and sour decaying substances. *Anguillula aceti* Ehrenberg is from one to two millimetres in length, and lives in vinegar.

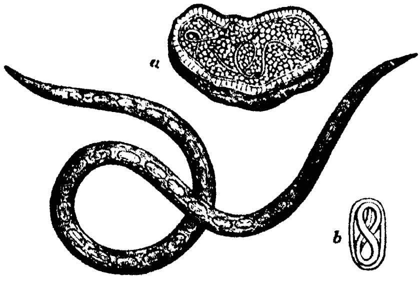


Fig. 118.—Young Wheat-Worm, greatly magnified. *a*, section of "cheat" exhibiting some worms and multitudes of eggs, magnified; *b*, an egg containing a worm ready to hatch.—From Curtis, after Bauer.

The genus *Chætosoma* lives free in the sea, and has a broad swollen head beset with fine hairs. It apparently connects the true Nematodes with *Sagitta*.

The second suborder, *Gordiacea* or hair-worms, differ in their mode of development from the true Nematode worms, the embryo of Gordius being armed with oval spines, thus reminding us in this respect of *Echinorhynchi*, but the embryos, larvæ and adult have a well-developed alimentary canal.

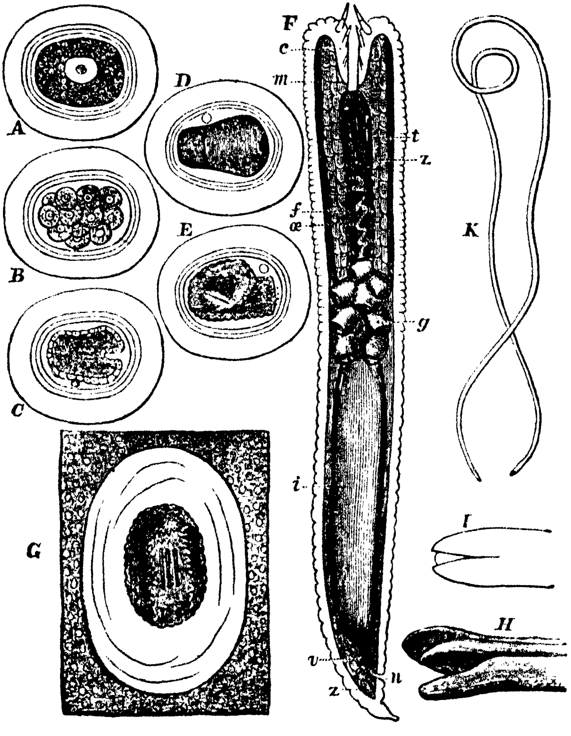


Fig. 119.—*Gordius aquaticus.* A, egg; B, egg undergoing segmentation of the yolk; C, embryo (gastrula) with the primitive stomach, an infold of the outer germinal layer of cells (ectoderm); D, embryo farther advanced; E, larva, with the three circles of spines retracted within the œsophagus; F, the same stage greatly enlarged to show the internal organs; *c*, middle circle of spines, the head being retracted; *m*, muscular layer (?); *t*, beak or proboscis; *i*, intestine; *z*, *z*, embryonal cells; *f*, excretory tube leading from *g*, the secretory glands; *œ*, œsophagus; *v*, rectum; *n*, anus. G, the second larva, encysted in a fish—(after Villot). H, *Gordius varius*, end of body of male, much enlarged. I, *Gordius aquaticus*, end of body of male, much enlarged. K, *Gordius aquaticus*, natural size.—(H, I, K, drawn from nature by J. S. Kingsley.)

The hair-worms belong to the genera *Mermis* and *Gordius*. In the former genus the head is beset with papillæ, and the end of the body of the male is undivided, while the oviduct of the female opens in the middle of the body. The larva is unarmed and has no metamorphosis. *Mermis acuminata* Leidy is pale brown and parasitic in the body of the caterpillar of the coddling moth; another species lives in the bodies of grasshoppers.

The true hair-worm, *Gordius*, has no papillæ on the head, and the tail of the male is forked, while the oviduct of the female opens at the end of the body. The following account of the development of the common *Gordius aquaticus* Linn. which is a parasite of the locust and other insects, and is common to Europe and this country, is taken from Villot's "Monographie des Dragonneaux."

The eggs (Fig. 119, *A*) are laid in long chains; they are white, and excessively numerous. The yolk undergoes total segmentation (Fig. 119, *B*). At the close of this period, when the yolk is surrounded by a layer of cells, the germ elongates at what is destined to be the head-end; this layer pushes in, forming a cavity, and in this stage it is called a "gastrula" (*C*). By this time the embryo becomes pear-shaped (*D*); then it elongates. Subsequently the internal organs of digestion are formed, together with three sets of stiff, spine-like appendages to the head, while the body is divided by cross-lines into segments. The head lies retracted within the body (*E*).

In hatching, it pierces the egg membrane by the aid of its cephalic armature, and escapes into the water, where it passes the early part of its life. Fig. 119, *F*, represents the embryo of *Gordius aquaticus* greatly magnified. It will be seen how greatly it differs from the adult hair-worm, having in this stage some resemblance to the *Acanthocephalus* by its cephalic armature, to the *Nematoidea* or thread-worms by its alimentary canal, and in the nature of its secretory glands to the larvæ (cercaria) of the Trematodes or fluke-worms. But the hair-worm differs from all these worms and even Mermis, a hair-worm much like and easily confounded with Gordius, in having a complete metamorphosis after leaving the egg.

When in this stage it incessantly protrudes and retracts its armed head, the spines being directed backward when the head is out.

In the first period of larval life the worm lives encysted in the bodies of aquatic fly larvæ. The vessel in which M. Villot put his Gordius eggs also contained the larvæ of Tanapus, Corethra, and Chironomus, small gnat-like flies. He found that each of these larvæ contained numerous cysts with larvæ of Gordius. He then removed the larvæ from the cysts, placed them on the gnat-larva, and saw the larval hair-worm work its way into the head of the gnat-larva through the softer part of the integument; during the process the spines on the head, reversing their usual position, enabled the worm to retain its position and penetrate farther in. Then, finding a suitable place, it came to rest, and remained immovable. Then the fluids bathing the parts coagulated and formed a hard, granulated sac. This sac at first closely envelopes the body, then it becomes looser and longer, the worm living in the anterior part, the front end of the sac being probably never closed. In this first larval state the worm is active.

In the second larval period the young hair-worm lives motionless and encysted in the mucous layer of the intestines of such small fish as prey on the gnat-larvæ. A minnow, for example, swallowing one of the aquatic gnat-larvæ, the encysted larva becomes set free by the process of digestion in the stomach of the fish; the cyst dissolving, the young hair-worm itself becomes free in the intestine of its new host. Immediately it begins to bore, aided by the spines around the head, into the mucous membrane lining the inner wall of the intestine of the fish, and there becomes encysted, the worm itself lying motionless in its new home, with its head retracted and the tail rolled in a spiral. The cyst is either spherical or oval. (Fig. 119, *G.*)

The return to a free state and an aquatic life occurs in the spring, five or six months after the second encystment. It then bores through its cyst, and passes into the intestinal cavity of the fish, and from thence is carried out with the fæces into the water. On contact with the water great changes take place. The numerous transverse folds in the body disappear, and it becomes twice as long as before, its head-armature disappears, the body becomes swollen, milky, and pulpy. It remains immovable in the water for a variable period, and then increases in size; the integument grows harder, and when about two inches long it turns brown and begins to move. Most hair-worms live in ground beetles and locusts, twining round the intestines of their host, finally passing out of the anus. They are often seen in fresh water pools, twisted into knots, whence their name *Gordius*. They sometimes occur in horse-troughs, whence they are supposed by the ignorant to be transformed horse-hairs.

Order 3. *Chætognathi.*—This group is represented by a single genus, *Sagitta*, which, from the singularities in its form and structure, has by different authors been referred to the Crustacea, the Mollusca and even the Vertebrates. Its development and structure show that it is closely allied to the Nematode worms. It is about two centimetres (nearly one half inch) in length, and is found swimming at the surface of the ocean in different parts of the world. The lateral and caudal fin-like expansions of the skin of the end of the body gives it a fish-like appearance. There is a well-defined head, with several curved spines on each side of the mouth, which serve as jaws; besides these, at the sides of the head are four sets of short, strong spines. In the young Sagitta there are also a few pairs of lateral spines behind the head, but these afterwards disappear. The alimentary canal forms a straight tube terminating in a ventral opening near the posterior fourth of the body. The nervous system consists of a brain from which two nerves are distributed to the eyes, and two lateral nerves pass backward to a large ventral ganglion lying near the middle of the body, from which two threads pass backwards. The sexes are united in the same individual, the two long tubular ovaries communicating by two long ciliated oviducts, each with a separate outlet at the base of the tail. Behind the ovaries and anus are two chambers in which the spermatic particles are developed from masses of cells floating freely in the perivisceral fluid, and escaping by a lateral duct on each side of the tail. The egg passes through a morula and gastrula stage (Fig. 120). The primitive opening (*a*) afterwards closes and a new opening is made at the opposite pole, which is the permanent mouth. The embryo is oval at first, but soon elongates, and the form of the adult is attained before the Sagitta leaves the egg. *Sagitta elegans* Verrill is about 16 millimetres in length, and is common in the waters of New England.

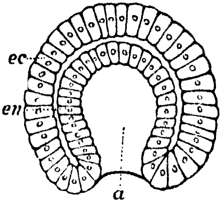


Fig. 120.—Gastrula of Sagitta.—After Kowalevsky.

CLASS II.—NEMATELMINTHES.

Round-bodied worms, with a dense integument, not jointed; with an alimentary canal (except in Echinorhynchus); no water-vascular or respiratory system; the nervous system usually reduced to a brain and two nervous threads passing along the body; with excretory organs. The head sometimes hooked or spinulated; and except in Echinorhynchus and Gordiacea no metamorphosis, the young hatching in the form of the adult. Mostly parasitic, and usually bisexual.

Order 1. *Acanthocephali.*—Cylindrical, with a beak armed with hooks, without mouth or digestive tract. (Echinorhynchus.)

Order 2. *Nematodes.*—Long, slender, cylindrical, with a mouth and intestine; but no metamorphosis. Suborder 1. True *Nematodes* (Ascaris, Oxyuris, Eustrongylus, Trichocephalus, Trichina, Filaria, Anguillula, Echinoderes). Suborder 2. *Gordiacea* (Mermis, Gordius).

Order 3. *Chaetognathi.*—Having a well-marked head, with lateral and caudal fin-like expansions of the skin; hermaphrodite. (Sagitta.)

Laboratory Work.—These worms are to be mainly sought for in the alimentary track of fishes and mammals, while Sagitta may be caught with the tow-net. They may be studied with good success besides the ordinary mode of dissection, by cross-sections for the microscope.

CLASS III.—ROTATORIA (*Rotifers*).

General Characters of Rotifers.—The Rotifers, or wheel-animalcules, are abundant in standing water, in damp moss, etc., and in the ocean, and are so transparent that their internal anatomy can be studied without dissection, while they are so minute, being from one fortieth to three hundredths of an inch in length ($\frac{5}{8}$ to $\frac{8}{4}$ mm.), that high powers of the microscope are needed in studying them. They are of special interest from the fact that after being dried for months to such a degree that little if any moisture is left in the body, they may be revived and become active. Professor Owen has observed the revivification of a Rotifer after having been kept for four years in dry sand.

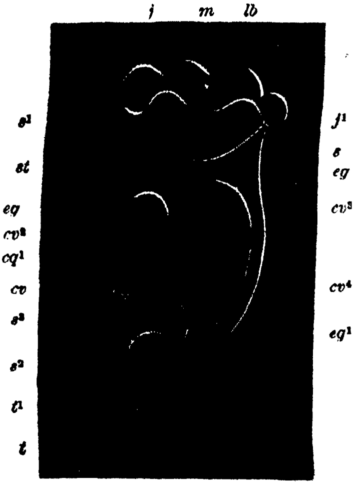


Fig. 121.—*Squamella oblonga*, magnified 200 diameters. A view from below: shell or carapace (s, s^1, s^2); s, the anterior transverse edge of the carapace; s^1, the anterior, and s^2, the posterior corners of the carapace; s^3, the border of the oval, flat area which occupies the lower face of the carapace; *lb*, the cilia-bearing velum of the head; t, the fork of the tail (t^1); *m*, the mouth; *j*, jaws; j^1, muscles which move *j*; *st*, stomach; *cv*, the contractile vesicle, or heart of the excretory system; cv^1, cv^2, the right, and cv^3, cv^4, the left excretory vessels; *eg*, eg^1, eg^2, two largely developed young.—After Clark.

As an example of the ordinary type of Rotifer we may cite *Squamella oblonga* (Fig. 121), which is allied to *Brachionus*. The characteristic organ of the wheel-a is the *velum* (*lb*) or of ciliated wheel-like flaps on each side of the head, which is comparable to the velum of the larval mollusk. By means of the rotatory movements of this velum the creature is whirled swiftly around. The body is broad and flattened, with the walls often dense, chitinous, sometimes shell-like, and variously sculptured, or the animal may be long and worm-like, as in *Rotifer vulgaris* (Fig. 122). The body is composed of several, not over six, segments. A Rotifer may, in fact, be regarded as an advanced *trochosphere* or more properly *cephalula*, and comparable with the larvæ or cephalulæ of mollusks, Polyzoa, Brachiopoda and the Annelids. The alimentary canal consists of a funnel-like cavity, the mouth, which may be central, or situated on one side of the head; it leads to the *mastax* or pharynx-like muscular sac, supporting a complicated set of chitinous teeth within (malleus and incus) which seize and masticate the food, which, through the rotary action of the velum, passes down the buccal channel or mouth-opening, and lodges within the mastax. The so-called salivary glands are two large, clear, vesicular glands, which are attached to the funnel and rest on the summit of the mastax. The latter opens into the œsophagus, "a membranous tube, capable of great expansion and contraction, but varying much in length and diameter in different genera." Gosse also states that a current of water appears to be almost constantly setting through the funnel and mastax, and thence through the œsophagus into the stomach; the latter is quite large, and provided with so-called "pancreatic" glands, emptying into the anterior end. There are also hepatic follicles and cæca, while the intestine ends in a rectum and cloaca, the latter opening at the base of the tail. In *Notommata*, the digestive canal ends in a blind sac, and in such male Rotifers as are known, there is no digestive cavity, the canal being represented by a solid thread.

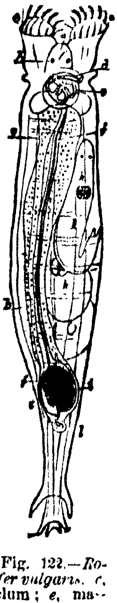


Fig. 122.—*Rotifer vulgaris*. *c*, velum; *e*, mastax; *g*, digestive canal; *k*, eggs.

There are no vascular or respiratory organs, but a system of long, convoluted excretory tubes, one on each side of the body, which, as in the Trematodes and Cestodes, unite in a common, large contractile vesicle which opens into the end of the intestine. These tubes, which are in places ciliated, correspond to the segmental organs of Annelids; they are open at the end, the cavity of the tubes thus communicating with the body-cavity.

The nervous system is very simple, consisting of a rather large ganglion situated behind one wing of the velum, and lying just under an eye-spot. A supposed organ of hearing, consisting of a sac filled with calcareous matter, is attached to the ganglion.

The sexes are distinct, and the male and female reproductive glands open into the cloaca. The sexes are, moreover, remarkably unlike, the males being much smaller than the females, rudimentary, sac-like in form, without any digestive sac, and are very short-lived. Some Rotifers produce what are called *winter* as well as *summer* eggs; the former being, as in some Turbellarian worms and *Polyzoa*, covered with a hard shell to resist the extremes of the winter temperature. The summer eggs develop without being fertilized, while the winter eggs are fertilized, those of *Lacinularia*, however, according to Huxley, not being impregnated.

The eggs of Brachionus are attached by a stalk to the hinder part of the body of the female. The following remarks apply to the mode of development of the female eggs, which are quite distinguishable from the masculine ones. The eggs undergo total segmentation, and the outer layer of cells resulting from subdivision forms the blastoderm, and when this is developed the formation of the organs begins. The first occurrence is an infolding of the blastoderm (ectoderm) forming the primitive mouth, which remains permanently open, the mouth not opening at the opposite end as in *Sagitta*, but the entire development of the germ is much as in the mollusk *Calyptræa*, as Salensky often compares the earliest phases of development of this Rotifer with those of that mollusk. The "trochal disk," or velum, arises in certain mollusks, as a swelling on each side of the primitive infolding. There is soon formed at the bottom of the primitive infolding a new hole or infolding of the ectoderm, which is the true mouth and pharynx, while a swelling just behind the mouth becomes the under lip. The stomach and intestine arise originally from the endoderm.

Soon after, the two wings of the velum become well marked (Fig. 123, *v*), and their relation to the head is as constant as in Calyptræa. The tail (*t*) becomes conical, larger, and the termination of the intestine and anal opening is formed at the base.

The internal organs are then elaborated; first the nervous system, consisting of but a single pair of ganglia arising from the outer germ-layer (ectoderm). Soon after the sensitive hairs arise on the wings of the velum.

Fig. 123 represents the advanced embryo, with the body divided into segments, the pair of ciliated wings of the velum (*v*), and the long tail (*t*). At this time the shell begins to form, and afterwards covers the whole trunk, but not the head.

The inner organs are developed from the inner germ-layer (endoderm), which divides into three layers, one forming the middle part of the intestine, and the two others the glands and ovaries. The pharyngeal jaws arise as two small projections on the sides of the primitive cavity. The male develops in the same mode as the female.

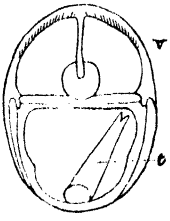


Fig. 123.—Brachinus nearly ready to hatch.—After Salensky.

Though the development of the Rotifers, so far as known, is more like that of the mollusks than true worms, the Rotifers may be regarded as a generalized cephalula form, representing the larval forms of Annelids and mollusks, with decided affinities, when we consider their chitinous covering or carapace, the fold of the intestine, and the single nervous ganglion, to the *Polyzoa*, and with more remote resemblances to the Brachiopods. They are on the whole generalized forms. A few species are parasitic: *Albertia* living internally, and *Balatro* on the surface of the Nais-like worms. With the lower Rotifers are associated a group of worm-like forms represented by *Chætonotus*, *Ichthydium*, etc., and forming the group *Gastrotricha*. They have no mastax, and the body is only ciliated near the end. Through *Dinophilus*, a Turbellarian worm, they are connected with the flat worms. The genus *Echinoderes* is also regarded by Claus as a low Rotifer. It seems quite apparent from this that the Rotifers are a type which has originated from worms resembling the generalized Turbellarian form, and which connects the latter with the *Polyzoa, Brachiopods*, and possibly the *Mollusca*, the latter branch being probably a modified vermian type, and with an ancestry not unlike that of the Rotifers and aberrant, generalized *Polyzoa* and *Brachiopoda*. The classification of the *Rotatoria* is in an unsettled state, the group probably consisting of three orders, viz.: the true *Rotatoria*, the *Echinoderidæ*, and *Gastrotricha*.

CLASS III.—ROTATORIA.

Worms with usually more or less solid segments, very unequally developed, bearing a ciliated velum, the mouth opening into a mastax; sexes separate, the males much smaller, more rudimentary than the females. A small nervous ganglion. No circulatory apparatus, but with a voluminous excretory (water-vascular) organ.

(Albertia, Asplanchna, Hydatina, Brachionus, Rotifer, and the highest form, Floscularia.)

Laboratory Work.—The Rotifers can only be studied while alive and as transparent objects. Little is known about the American species.

CLASS IV.—POLYZOA (*Moss Animals*).

The *Polyzoa*, though not commonly met with in fresh water, are among the commonest objects of the seashore. They are minute, almost microscopic creatures, social, growing in communities of cells (called polyzoaria or corms), forming patches on seaweeds and stones (Fig. 124, *Membranipora solida* Pack.). Certain deep-water species grow in coral-like forms (Fig. 125, *Myriozoum subgracile* D'Orbigny), while the chitinous or horny *Polyzoa* (Fig. 126, *Halophila borealis* Pack.), are often mistaken for sea-weeds on the one hand, and Sertularian Hydroids on the other. From their likeness to mosses the name *Bryozoa* was given to the group by Ehrenberg, a year after Thompson (1830) had called them *Polyzoa*, so that the latter name has priority.

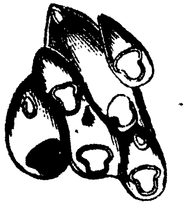


Fig. 124.—Cells of Sea-mat, enlarged.

The simpler form of Polyzoon is a worm-like creature enclosed in a minute, deep, horny cell, with the alimentary canal bent on itself and terminating in a vent situated near the mouth, the latter surrounded, in the fresh-water forms, with a horseshoe-shaped crown, or in the marine species a circle of slender ciliated tentacles. The animal when disturbed withdraws into its tube or shell, which is often transparent, allowing it to be examined when alive. The cells are rarely single, but a *cormus, polyzoarium* or polyzoon-stock is formed by the budding of numerous cells from the one first formed. The single polyzoon is called a *polypide*, and its cell a *cystid*. In *Pedicellina*, the simplest polyzoon, the polypide has no cystid or cell. The cells are, in the marine forms, usually closed, and independent of each other. The wall forming the cell is called the *endocyst ;* it comprises the ectoderm proper, with a portion (parietal layer) of the mesoderm forming the soft lining of the cell.

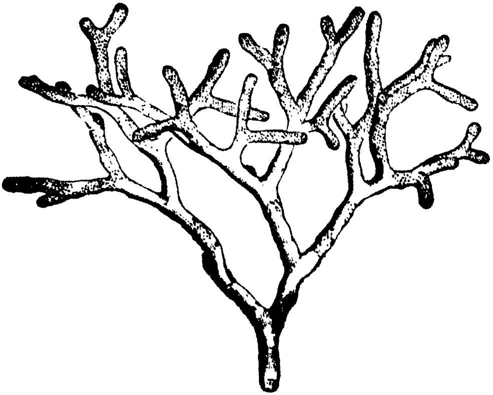


Fig. 125.—Branching marine Polyzoon. Corm of *Myriozoum subgracile*, natural size.

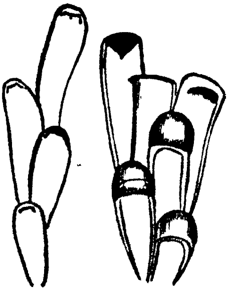


Fig. 126.—*Halophila borealis*, enlarged.

The mouth is situated on a disk (*lophophore*, Fig. 127, *B*), bearing the tentacles, which are hollow processes of the body-walls, communicating with the body-cavity, the blood flowing into them, there being aërated, while they are externally ciliated. They serve both to catch food and for respiration as makeshift gills. Hyatt states that the tentacles are used not only to catch the prey, but for a multitude of other offices. They are each capable of independent motion, and may be twisted or turned in any direction; bending inwards, they take up and discard objectionable matter, or push down into the stomach and clear the œsophagus of food too small to be acted upon by the parietal muscles. They are also employed offensively in striking an intrusive neighbor, and their tactile power, sensitive to the slightest unusual vibration in the water, warns the polypide of the approach of danger.

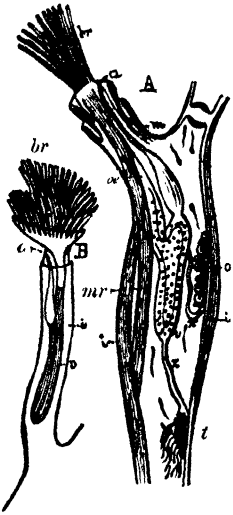


Fig. 127.—Organization of a Polyzoon. A, *Paludicella Ehrenbergii*. B, *Plumatella fruticosa*. *br*, tentacular branchiæ of lophophore; *œ*, œsophagus; *v*, stomach; *r*, intestine; *a*, anus; *i*, cell; *x*, posterior, *x*¹, anterior cord, at the insertion of which into the body the generative products are developed: *t*, testes; *o*, ovary; *m*, [illegible] of the ante- [illegible] cell; *mr*, muscle.—

The digestive canal hangs free in the body-cavity, only attached by the mouth and anus to the walls of the body. It consists of a pharynx, a large stomach, and an intestine which lies by the side of the pharynx, since the canal has a simple deep dorsal flexure, the vent being situated on the dorsal or cardiac side, near the mouth. Usually the stomach is tied by a sort of ligament (*funiculus*) to a point on the body-walls, near the mouth. The nervous system is represented by a double ganglion forming a single mass situated between the mouth and vent; it is highly contractile and changeable in form. There is no heart nor any circulatory apparatus. The sexes are united in a single polypide, the glands forming masses growing on the funiculus or in the walls of the body. The body, especially the lophophore, is retracted and pushed out by muscles arranged in pairs on either side. As seen in *Fredericella*, a fresh-water form, the alimentary canal "hangs from the lophophore, occupying the centre of the polypide, and floating freely in the rapidly moving blood" (Hyatt). The yellowish œsophagus, the stomach barred with brown, and the brownish intestine are balanced upon a fold of the intestine (the invaginated fold), which is retained in the cell by the retentor muscles, and is surrounded by a large sphincter muscle. There are two sets of large retractor muscles, one on each side of the digestive canal, and arising from two common bases; each large trunk subdivides into three branches, the retractor of the stomach, of the lophophore, and of the anus. The crown of tentacles is swayed by these muscles in every direction, or when alarmed the polypide may withdraw by their aid into the cell, as the finger of a glove may be inverted within the empty palm. This may be done with great rapidity or slowly. The process has thus been graphically described by Hyatt: "The polypidal endocyst is first turned inwards, folding upon itself, and prolonging the permanently invaginated fold below. The tentacles, arriving at the edge of the cœnœcial orifice, are pressed into a compact bundle by the action of their own muscles, and, together with the lophophore, are dragged into the cell by the continued invagination of the endocyst until they are wholly enclosed and at rest within the sheath formed for them by the inverted walls of the tube. The sphincter muscle then closes the cœnœcial orifice above, and the process of invagination is completed.

"The polypide in its exserted state is buoyed up and sustained by the pressure of the fluids within. Consequently, when invaginated, it displaces an equal bulk of these in the closed cœnœcium, and their reaction, aided by the contraction of the muscular endocyst, is sufficient to evaginate the whole.

"The evagination begins with the relaxation of the sphincter, which permits the ends of the tentacles to protrude.

These daintily feel about for the cause of the alarm, and, if they fail to detect the proximity of an enemy, the whole fascicle is cautiously pushed out, and the sentient threads suddenly and confidently unfolded.

"The polyzoön reasons from the sense of touch inherent in its tentacles, and cannot be induced to expose itself above the cœnœcium until thoroughly satisfied by these sensitive feelers that no danger is to be apprehended. In fact, these plant-like creatures, singly mere pouches with a stomach hanging in the midst, exhibit greater nervous activity and 'animality,' than we find among the more highly organized *Ascidia*, or shell-covered *Brachiopoda*."

The *epistome* is a fold of the lophophore, used to close the mouth and thus prevent the food from escaping from the mouth. *It is tongue-like and very pliable.* "*The border is capable of a tactile motion similar to that of the human tongue, and it takes cognizance of what passes into the mouth by frequent and repeated jerks toward the aperture*" (Hyatt). It is situated immediately over the ganglionic mass, and between the anus and mouth.

The *Polyzoa*, as regarded by Hyatt and others, are structurally nearly related to the Brachiopods, the higher forms of which, such as *Terebratula* and *Rhynconella*, have the respiratory tentacles similarly placed around the disk or lophophore, which is perforated at the centre by the mouth, and from which the alimentary canal hangs, with a dorsal flexure and anus near the mouth. "The extension of the lophophore into two or three spiriform arms, the complex structure of the tentacles and of the muscular and nervous systems, are all more or less foreshadowed by the condition of these systems among the higher *Polyzoa*." On the other hand, the *Polyzoa* are closely related to the worms, the Gephyrean worm, *Phoronis*, being the connecting link. The mode of development of the *Polyzoa* and *Brachiopoda* are quite similar, as will be seen farther on, and owing to these decided similarities in development and anatomy, the *Polyzoa* and Brachiopods form a natural group or series, distinct on the one hand from the *Rotatoria*, and on the other from the mollusks and worms.

Certain branching marine forms are provided with organs like birds' heads, situated on a stalk and called *avicularia*, with a movable jaw-like appendage, which keeps up an incessant snapping. Beside the *avicularia*, there are, as in *Scrupocellaria*, long bristle-like appendages to the cells, called *vibracula*.

There are no organs of special sense in the *Polyzoa*, unless the epistome may be regarded as an organ of sense, and the nervous system consists of a single rounded ganglion (*Fredericella*), or, as in *Plumatella*, a double ganglion, situated between the mouth and vent, from which one set of nerves are distributed to the epistome, lophophore, tentacles, and evaginable endocyst, and another set to the various parts of the alimentary canal. A so-called colonial nervous system is supposed to exist in the Polyzoa, as when the cœnœcium in some forms is touched all the polypides become alarmed, which indicates that a set of nerves connect the different polypides, though no such nerves have yet been discovered. The fresh-water *Polyzoa* are not sensitive to light, nor to noises, only to agitation of the water in which they dwell.

All the *Polyzoa* are hermaphrodite, the ovary and male glands residing in the same cystid, the testis being situated near the bottom and attached to the funiculus, while the ovary is attached to the walls of the upper part of the cell.

Allman regards the polypide and cystid as separate individuals. The singular genus *Loxosoma* is like the polypide of an ordinary Polyzoan, but does not live in a cell (cystid). On the other hand, we know of no cystids which are without a polypide. Remembering that the cystids stand in the same relation to the polypides as the hydroids to the medusæ, as Nitsche insists, we may regard the polypides as secondary individuals, produced by budding from the cystids. The large masses of cells forming the moss-animal, which is thus a compound animal, like a coral stock, arises by budding out from a primary cell. The budding process begins in the endocyst, or inner of the double walls of the body of the cystid, according to Nitsche, but according to an earlier Swedish observer, F. A. Smitt, from certain fat bodies floating in the cystid.

The *Polyzoa* are divided primarily into the *Entoprocta*, represented by *Loxosoma* alone, in which the vent is situated within the circle of tentacles, and the *Ectoprocta*, in which the vent lies outside of the lophophore—a group comprising all the higher *Polyzoa* (*Gymnolæmata* and *Phylactolæmata*).

The development of the *Polyzoa* is not very complicated. In the marine forms, as studied by Barrois, the germ passes through a morula stage ; after which the cells are arranged into two halves, separated by a crown of cilia ; at this stage it is called a *blastula*. At the time of birth the ciliated germ is a disk-shaped gastrula, with two opposite faces or ends, separated by the crown, one (aboral) bearing in its centre the mouth-opening. This ciliated free-swimming top-like gastrula stage is called a *trochosphere*.

After swimming about as ciliated larvæ (trochospheres), the shell or ectocyst develops, and the larva becoming stationary, the cystid forms, its calcareous shell develops, and finally the polypide is indicated, and the primitive cell is gradually formed.

As seen in *Phalangella flabellans*, the larva, after becoming fixed to some object, consists of a white pyriform mass, closely enveloped by an ectocyst, with numerous fat globules between the latter and the white mass. The ectocyst swells into a discoidal sac, with endocyst, ectocyst, and an external zone, while the internal whitish mass transforms into the polypide. The discoidal sac formed by the endocyst constitutes simply the basal disk of the primitive cell. The future opening of the cell appears on the upper surface of the cell. The budding out of the secondary cells of the *polyzoarium* or corm then takes place. It begins by the appearance of a cell placed in front and below the primitive cell, and which borders it on each side ; its secondary cell then divides into two, each of which successively gives origin to three cells, and we thus arrive at an *Idmonea* stage ; and finally the *Phalangella* stage is reached, the process being a dichotomous mode of budding quite analogous to that which produces the broad, flattened corm of *Escharina*.

The development of *Membranipora pilosa*, which is very abundant on our shores, growing on sea-weeds, is of singular interest. The free-swimming ciliated larva is provided with a bivalve shell, and was originally described as a Lamellibranch larva under the name of *Cyphonautes.* Schneider discovered that it was a young *Membranipora.* Barrois, who has traced its complete history, states that its metamorphosis is fundamentally like that of the other marine *Polyzoa.* *Flustrella hispida* passes through a similar Cyphonautes stage.

In *Loxosoma* young resembling the adult bud out like polyps. Nitsche does not regard this budding process as an alternation of generations, but states that in *Polyzoa* of the family of *Vesiculariidæ,* this may occur, as in the latter some cystids form the stem, and others (the *zoœcia*) produce the eggs. Most fresh-water *Polyzoa* reproduce by the development of winter buds or eggs surrounded by a horny case, and developing from the funiculus.

To recapitulate: the *Polyzoa* increase (*a*) by budding; (*b*) by normal (summer) eggs, and by producing *statoblasts,* or winter eggs. In reproducing from summer eggs, the young pass successively through a *morula, blastula, gastrula* and *trochosphere* stage before attaining maturity.

The most aberrant Polyzoan is *Rhabdopleura mirabilis* Sars, which occurs in from 100 to 300 fathoms on the coast of Norway. It differs from other forms by the want of an endocyst or mantle, whence it moves up and down in its cell, without being attached to the opening, the muscles usually present being wanting, the cord by which it is attached to the bottom of its long, slender tubular cell being contractile. The lophophore is much like that of the fresh-water Polyzoans, consisting of two long arms, bearing two rows of slender tentacles. The epistome is represented by a large round disk.

The marine *Polyzoa* occur at great depths, and a few species are cosmopolitan; the type is very persistent, and occurs in the oldest Silurian strata, the earliest forms being very similar to their living descendants.

CLASS IV.—POLYZOA.

Animals usually forming moss-like or coral-like calcareous or chitinous masses called corms, each cell containing a worm-like animal, with the digestive tract flexed, the anus situated near the mouth. The body usually drawn in and out of the cell by the action of retractor and adductor muscles. The mouth surrounded by a crown of long tentacles. No heart or vascular system. Nervous system consisting of a single or double ganglion situated between the mouth and vent, with nerves proceeding from it. Hermaphroditic; multiplying by budding or eggs. The embryo passing through a morula, gastrula and trochosphere stage, the corm being formed by the budding of numerous cells from a primitive one.

Order 1. *Entoprocta.*—Vent within the lophophore. (Loxosoma.)

Order 2. *Ectoprocta.*—Vent without the lophophore. (Lepralia, Eschara, Idmonea, Myriozoum.)

Laboratory Work.—The Polyzoa are too small to dissect, and must be studied while alive as transparent objects, and may be kept in aquaria. The corms in part or whole can be mounted for the microscope as opaque objects.

CLASS V.—BRACHIOPODA (*Lamp Shells*).

General Characters of Brachiopods.—This group is named *Brachiopoda* from the feet-like arms, fringed with tentacles, coiled up within the shell, and which correspond to the lophophore of the *Polyzoa* and the crown of tentacles of the Sabella-like worms. From the fact that the animal secretes a true, bivalved, solid shell, though it is usually inequivalve, *i.e.*, the valves of different sizes, the *Brachiopoda* were generally, and still are by some authors, considered to be mollusks, though aberrant in type. They may be regarded as a synthetic type of worms, with some superficial molluscan features. The shell of our common northern species, *Terebratulina septentrionalis*, which lives attached to rocks in from ten to fifty or more fathoms north of Cape Cod, is in shape somewhat like an ancient Roman lamp, the upper and larger valve being perforated at the base for the passage through it of a peduncle by which the animal is attached to rocks. The shell is secreted by the skin (ectoderm), and is composed of carbonate (*Terebratulina*) or largely (*Lingula*, Fig. 133) of phosphate of lime. It is really the thickened integument of the animal, the so-called mantle being the inner portion of the skin, containing minute tubular canals which do not open externally.

The body of Brachiopods is divided into two parts, the anterior or thoracic, comprising the main body-cavity in which the arms and viscera are contained, and the caudal portion, *i.e.* the peduncle. The part of the body in which the viscera lodge is rather small in proportion to the entire animal, the interior of the shell being lined with two broad lobes, the free edges of which are thickened and bear setæ, as seen distinctly in *Lingula*. The body-cavity is closed anteriorly by a membrane which separates it from the space in which the arms are coiled up. The "pallial chamber" is situated between the two lobes of the mantle (*pallium*) and in front of the membrane forming the anterior wall of the body-cavity. In the middle of this pallial chamber the mouth opens, bounded on each side by the base of the arms. The latter arise from a cartilaginous base, and bear ciliated tentacles, much as in the worm *Sabella*. In *Lingula*, *Discina*, and *Rhynconella*, they are developed, as stated by Morse, in a closely-wound spiral, as in the genuine worms (*Amphitrite*). In *Lingula* the arms can be partially unwound, while in *Rhynconella* they can not only be unwound but protruded from the pallial chamber. In many recent and fossil forms the arms are supported by loop-like solid processes of the dorsal valve of the shell, but when these processes are present the arms cannot be protruded beyond the shell. The tentacles or cirri on the arms are used to convey to the mouth particles of food, and they also are respiratory in function, there being a rapid circulation of blood in each tentacle, which is hollow, communicating with the blood-sinus or hollow in each arm, the sinus ending in a sac on each side of the mouth.

The digestive system consists of a mouth, œsophagus, stomach, with a liver-mass on each side, and an intestine. Fig. 128 shows the relation of the mouth and digestive canal to the head and arms, as seen in a longitudinal section of the anterior part of the body of *Lingula.* The mouth is bordered by two membranous, highly sensitive and movable lips. The stomach is a simple dilatation of the alimentary canal, into which empty the short ducts of the liver, which is composed of masses of cœca. The liver originally arises as two diverticula or offshoots of the stomach. The short intestine ends in a blind sac or in a vent, and is, with the stomach, freely suspended in the perivisceral cavity by delicate membranes springing from the walls of the body. (Fig. 129.) In those Brachiopods allied to *Terebratula, Terebratulina, Thecidium, Waldheimia, Rhynconella,* etc., the stomach ends in a blind sac, and there is no vent, the rejectamenta escaping from the mouth. In *Lingula* and *Discina* there is a vent which terminates anteriorly on the right side. In *Lingula* the intestine makes a few turns, while in *Discina* it makes a single turn to the right.

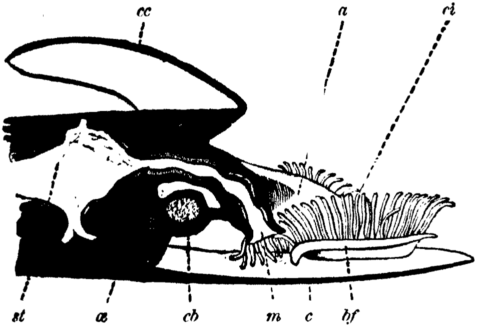


Fig. 128.—Longitudinal section of the anterior portion of *Lingula. m*, mouth; *œ*, œsophagus; *st*, stomach; *a*, arm; *ci*, cirri; *bf*, brachial fold; *cb*, cartilaginous base of arm; *s*, sinus leading to the arm; *cc*, cephalic collar or pallial membrane.—After Morse.

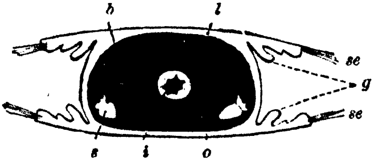


Fig. 129.—Transverse section of *Lingula. b*, bands suspending the intestine in the perivisceral cavity; *i*, intestine; *s*, segmental organ; *o*, ovaries; *l*, liver; *g*, gills; *se*, setæ.—After Morse.

The nervous system consists of two small ganglia above, and an infraœsophageal pair of larger ganglia, and there are two elongated ganglia behind the arms, from which nerves are given off to the dorsal or anterior lobe of the mantle. From the infraœsophageal ganglia two lateral ventral cords pass backwards, in their tract sending off delicate threads, but with no ganglionic enlargements, except in *Discina*, where they terminate each by a ganglion in the last two posterior muscles. Morse has discovered the presence of auditory capsules in *Lingula*.

Respiration is mainly carried on in the mantle (pallial membrane). In *Lingula* the pallial membrane is divided into oblique transverse sinuses, which run parallel to each other. From these arise, says Morse, numerous flattened ampullæ, which are highly contractile. The blood courses in regular order up and down these sinuses, entering each of the ampullæ in turn. Fig. 130 represents a row of five ampullæ with indications of the course taken by the blood-disks. These ampullæ have not been found in *Discina*, though the pallial sinuses are very prominent. The breathing process is also carried on in the tentacles or cirri.

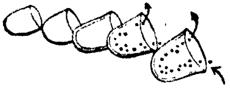


Fig. 130.—Ampullæ of blood sinuses, showing course taken by the blood.—After Morse.

Intimately connected with the vascular system is a glandular portion of the tubular part of the segmental organs of the *Brachiopoda*, which is supposed to represent similar parts in worms as well as the glandular, excretory portion of the organ of Bojanus in mollusks, and is supposed to be depuratory or renal in function.

The reproductive system of *Brachiopoda* consists of ovaries, oviducts or segmental organs, Fig. 131, and spermaries. The sexes are probably separate in all *Brachiopoda* (Morse).

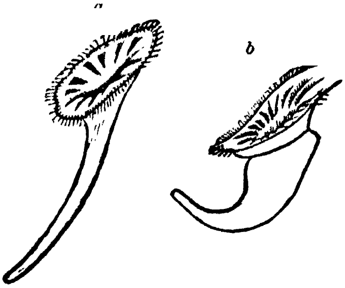


Fig. 131.—Segmental organs of Brachiopods. *a*, Discina; *b*, Terebratulina.—After Morse.

The ovaries are attached in *Discina* and *Lingula* to the delicate vascular membranes of the large sinuses in the pallial membranes, the vascular membranes being thrown into conspicuous ruffs when the eggs are ripe. In Terebratulina and Rynchonella they are not only similarly situated, but hang in clusters from the genital bands in the perivisceral cavity. The mature eggs detach themselves from the ovary to float freely in the perivisceral cavity, whence they pass into the flaring, ciliated mouths of the segmental organs, and are discharged by them into the water. These segmental organs or oviducts are tubular, trumpet-shaped, as in the true worms (Fig. 131). In Lingula, Discina, and Terebratulina, there is but a single pair, in Rhynconella two pairs. The external orifices of the oviducts form simple slits, while in Terebratulina they project from the anterior walls like tubercles, as in the true worms (Morse). The spermaries occur in the same situation in the perivisceral cavity as the ovaries. As observed in Terebratulina, by Morse, in a few hours after the eggs are discharged the embryos hatch and become clothed with cilia. Kowalevsky observed in the egg of Thecidium the total segmentation of the yolk (also observed in Terebratulina by Morse), until a blastoderm is formed around the central segmentation cavity, which contains a few cells. The similar formation of the blastoderm was seen in *Argiope*, but not the morula stage. After this the ectoderm invaginates and a cavity is formed, opening externally by a primitive mouth. The walls of this cavity now consist of an inner and outer layer (the endoderm and ectoderm). This cavity eventually becomes the digestive cavity of the mature animal.

In Terebratulina Morse observed that the oval ciliated germ became segmented, dividing into two and then three rings, with a tuft of long cilia on the anterior end (Fig. 132, A). In this stage the larva is quite active, swimming rapidly about in every direction.

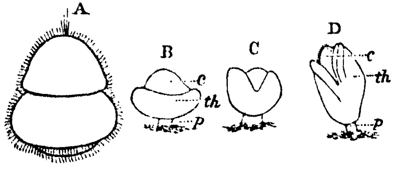


Fig. 132.—Larval stages of Terebratulina.—After Morse.

Soon after, the germ looses its cilia and becomes attached at one end as in Fig. 132, B (*c*, cephalic segment; *th*, thoracic segment; *p*, peduncular or caudal segment). The thoracic ring now increases much in size so as to partially enclose the cephalic segment, as at C. The form of the Brachiopod is then soon attained, as seen in D, in which the head (*c*) is seen projecting from the two valves of the shell (*th*), the larger being the ventral plate.

The hinge margin is broad and slightly rounded when looked at from above; a side view, however, presents a wide and flattened area, as is shown in some species of *Spirifer*, and the embryo for a long time takes the position that the Spirifer must have assumed (Morse). Before the folds have closed over the head, four bundles of bristles appear; these bristles are delicately barbed like those of larval worms. The arms, or cirri, now bud out as two prominences, one on each side of the mouth. Then as the embryo advances in growth the outlines remind one of a *Leptæna*, an ancient genus of Brachiopods, and in a later stage the form becomes quite unlike any adult Brachiopod known.

The deciduous bristles are then discarded, and the permanent ones make their appearance, two pairs of arms arise, and now the shell in "its general contour recalls *Siphonotreta*, placed in the family *Discinidæ* by Davidson, a genus not occurring above the Silurian." No eye-spots could be seen in Terebratulina, though in the young Thecidium they were observed by Lacaze-Duthiers. The young Terebratulina differs from Discina of the same age in being sedentary, while, as observed by Fritz Müller, the latter "swims freely in the water some time after the dorsal and ventral plates, cirri, mouth, œsophagus and stomach have made their appearance." Discina also differs from Terebratulina in having a long and extensible œsophagus and head bearing a crown of eight cirri or tentacles. Regarding the relations of the Brachiopods with the *Polyzoa*, Morse suggests that there is some likeness between the young Brachiopod and the free larva of Pedicellina. Fig. 133, B, represents the Terebratulina when in its form it recalls Megerlia or Argiope. C represents a later Lingula-like stage. "It also suggests," says Morse, "in its movements, the nervously acting Pedicellina. In this and the several succeeding stages, the mouth points directly backward (forward of authors), or away from the perpendicular end (D), and is surrounded by a few ciliated cirri, which forcibly recall certain *Polyzoa.* The stomach and intestine form a simple chamber, alternating in their contractions and forcing the particles of food from one portion to the other." Figure 133, E, shows a more advanced stage, in which a fold is seen on each side of the stomach; from the fold is developed the complicated liver of the adult, as seen in E, which represents the animal about an eighth of an inch long. The arms (lophophore) begin to assume the horseshoe-shaped form of *Pectinatella* and other fresh-water *Polyzoa.* At this stage the mouth begins to turn towards the dorsal valve, and as the central lobes of the lophophore begin to develop, the lateral arms are deflected as in F. In the stage G an epistome is marked, and Morse noticed that the end of the intestine was held to the mantle by an attachment, as in the adult, reminding one of the *funiculus* in the fresh-water Polyzoa. In tracing the development of Argiope, Kowalevsky has shown that the larva is strikingly like those of the Annelids, as well as the Tornaria stage of *Balanoglossus.*

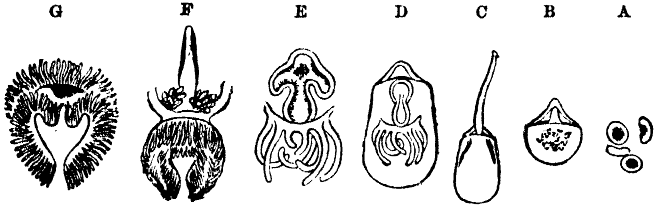


Fig. 133.—Later larval stages of Terebratulina.—After Morse.

While in their development the *Brachiopoda* recall the larvæ of the true worms, they resemble the adult worms in the general arrangement of the arms and viscera, though they lack the highly developed nervous system of the Annelids, as well as a vascular system, while the body is not jointed. On the other hand they are closely related to the *Polyzoa,* and it seems probable that the Brachiopods and *Polyzoa* were derived from common low vermian ancestors, while the true Annelids probably sprang independently from a higher ancestry. They are also a generalized type, having some molluscan features, such as a solid shell, though having nothing homologous with the foot, the shell-gland or odontophore of mollusks.

In accordance with the fact that the Brachiopods are a generalized type of worms, the species have a high antiquity, and the type is remarkably persistent. The Lingula of our shores (*L. pyramidata* Stimpson, Fig. 134) lives buried in the sand, where it forms tubes of sand around the peduncle, just below low-water mark from Chesapeake Bay, to Florida. It has remarkable vitality, not only withstanding the changes of temperature and exposure to death from various other causes, but will bear transportation to other countries in sea-water that has been unchanged. Living Lingulæ have been carried by Prof. Morse from Japan to Boston, Mass., the water in the small glass jar containing the specimens having been changed but twice in four months. The living species of this cosmopolitan genus differ but slightly from those occurring in the lowest fossiliferous strata. Between eighty and ninety living species are known, most of them living, except Lingula, which is tropical, in the temperate or arctic seas, while nearly 2000 fossil species are known. The type attained its maximum in the Silurian age, and in palæozoic times a few species, as *Atrypa reticularis*, extended through an entire system of rocks and inhabited the seas of both hemispheres.

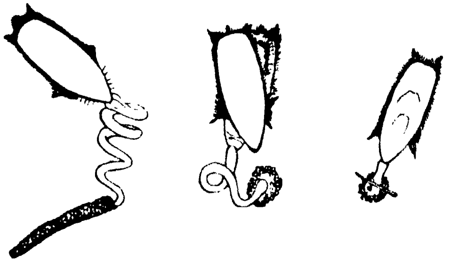


Fig. 134.—*Lingula pyramidata* making sand-tubes; natural size.—After Morse.

CLASS V.—BRACHIOPODA.

Shelled worms, with a limestone or partly chitinous, inequivalve, hinged or unhinged shell, enclosing the worm-like animal; with two spirally coiled arms provided with dense ciliated cirri or tentacles, and capable of reaching *to or beyond the edge of the gaping shells; alimentary canal with the mouth opening between the arms, an œsophagus, stomach with a liver-mass on each side, and a short intestine ending in a blind sac, and with the stomach freely suspended in the perivisceral space. Nervous system consisting of a ganglion above and beneath the œsophagus, and two lateral ventral widely-separated threads. No eyes in the adult, but present in the larvæ of Argiope and Thecidium; auditory sacs present in Lingula. No circulatory system, the blood impelled through the visceral interspaces and tentacular sinuses by ciliary action alone. Respiration carried on mainly in the mantle and also in the arms. The sexes distinct. One or two pairs of segmental organs. The germ passes through a morula and gastrula stage, becoming a segmented ciliated larva like that of the true worms, which becomes sessile, the shell developing from the thoracic segment of the larva and gradually enclosing the animal.*

Order 1. *Testicardines.*—Shell calcareous, of prismatic structure, with hinge and teeth. Intestine ending in a blind sac. Mantle lobes united behind. (Families Terebratulidæ, Spiriferidæ, Rhynchonellidæ, Strophomenidæ, and Productidæ.)

Order 2. *Ecardines.*—Shell without a hinge; arms without a calcareous loop and with no median lobe. Intestine either ending in a blind sac or with a vent opening anteriorly on the right side. (Families Craniidæ, Disciniidæ, and Lingulidæ.)

Laboratory Work.—Specimens of Terebratulina can be dredged in from ten to fifty fathoms on a rocky bottom north of Cape Cod, and the anatomy and development of the young be studied in living examples. Lingulæ can be obtained at Beaufort, N. C., and in the sandy shores southward. While the general structure can be studied from alcoholic specimens, the recent discoveries which have advanced our knowledge of the Brachiopods have been made on living, active individuals. The eggs are minute and have to be studied with high powers of the microscope.

CLASS VI.—TUNICATA (*Ascidians, Sea-squirts*).

General Characters of Tunicates.—While the Tunicates are an aberrant type of worms, with affinities on the one hand to the larvæ of the lower worms, *i.e.*, the Cercaria form of the Trematodes, on the other hand they have a startling resemblance in the tadpole-like young of many genera to the vertebrate *Amphioxus.* The position given to them between the Brachiopods and true worms not far from

Balanoglossus, is a provisional one. In a diagram showing the classification, *i.e.*, the affinities of the different classes of animals, the Tunicates may be represented as an independent branch sent off possibly from the Trematode stem, running parallel to the worms, near *Balanoglossus*, and ending a little below the level of *Amphioxus*. They have certainly few molluscan features, what do exist being superficial, and nothing to remind us closely of the *Polyzoa* or Brachiopods, and the class is here treated of because, in a serial arrangement of the classes of animals, the Tunicates can best be described at this place, rather than after the true worms, or immediately before the vertebrates.

The Ascidians are common just below low-water mark, either hidden in masses of mussels, attached to the rocks under sea-weeds, or the compound species may be found forming bright-colored masses on the piles of wharves and bridges, while the *Botryllus* grows on the leaves of eel-grass. For purposes of study the larger forms, such as *Ascidia*, *Cynthia*, and *Boltenia*, may be dredged. On placing a good-sized Ascidian in a vessel of fresh sea-water, it will be found to consist of a semi-transparent or quite opaque test with two openings, one lower than the other, as seen in *Molgula*, which looks, when the two orifices are protruded, like a double-necked bottle. The anterior or higher orifice or mouth is for the passage of currents of water into the respiratory sac, and the posterior, usually lower, excurrent orifice for the passage outwards of fæcal matter. The test is either delicate and semi-transparent, allowing the intestine and ovaries and liver to be detected, or it may be quite tough and opaque. It is rendered tough and hard by the presence of cellulose, a substance usually occurring in the walls of vegetable cells, but very rarely in animal tissues.

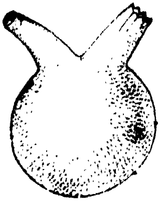


Fig. 135. — *Molgula Manhattensis*. — After Verrill.

Order 1. *Ascidiacea.*—As an example of the ordinary *Tunicates*, we will now study the internal anatomy of *Boltenia reniformis* (Fig. 136), which lives in from five to twenty-five fathoms off the coast of Northern New England, but which is sometimes thrown ashore on beaches.

On examining the test of this Ascidian, which is mounted on a long stalk, the oral or incurrent orifice is seen at the insertion of the stalk, and the atrial or excurrent orifice on the same side near the opposite end. On cutting open the thick test and throwing the flap over to the left, the delicate mantle or tunic is disclosed; it extends a short distance into the stalk or peduncle. This thin hyaline mantle is crossed by two sets of narrow raised muscular bands; the transverse fibres are arranged concentrically to the two orifices, so as to close or open them, the longitudinal ones curving outward from the left side.

Currents of sea-water laden with organic food pass into the oral orifice, which is surrounded by a circle of tentacles pointing inward, and thence into a capacious saccular branchial chamber within the mantle, which contracts at the bottom, where the œsophageal opening is situated. The walls of this chamber, which is over an inch long in a good-sized specimen, and gathered into fringed folds, is sieve-like with ciliated perforations (compare Fig. 137 *e*), making the walls like a lattice-work, the blood coursing through the vessels passing between the meshes of the sieve-like walls.

The œsophagus, which lies at the bottom of this branchial chamber, is also situated near the intestine passing over the anal end into the short stomach. The intestine is long, passing up to the insertion of the stalk, where it is held in place by muscular threads extending into the stalk and attached to the mantle; it then suddenly bends back and passes straight down to the vent, which opens opposite to the atrial orifice; the end of the intestine is in part revolute and provided with a fringe of about twenty filaments. The liver forms a broad and flat mass of a bright livid green, and consists of three flat lobes each composed of eight or nine lobules, with very short ducts enveloping the inner aspect of the intestine. The ovaries are two yellowish, large and long lobulated masses extending nearly the whole length of the body, while the right one is a little smaller, and situated in the fold of the intestine. The *atrium* is that region of the body-cavity which lies between the end of the intestine and the atrial or excurrent orifice; into this atrial region the fæces, eggs, etc., pass on their way to and out of the atrial orifice.

The simplest form of Tunicate is *Appendicularia*, which is tadpole-shaped, bearing a general resemblance to the larva of an ordinary Ascidian, so that it may be properly called a *larval* form. The Appendicularia is a pelagic animal, usually about a quarter of an inch in length, found floating at or near the surface when the ocean is calm, and occurring in all seas a few miles from land or in mid-ocean. It swims by means of its large, long, broad, flat tail, the body being oval or flask-shaped. In *Appendicularia flabellum*, as described by Huxley, the caudal appendage is three or four times as long as the body. The mouth leads into a large pharyngeal or branchial sac; a narrow œsophagus at the bottom of this sac leads to a spacious stomach, with two lobes, from the left one of which the intestine arises, curves and ends midway between the mouth and insertion of the tail. In the middle of the hæmal side (that side in which the heart is situated and bearing the atrial opening) is a fold of the wall of the pharyngeal cavity called the *endostyle*. On each side of this endostyle are two oval ciliated apertures,

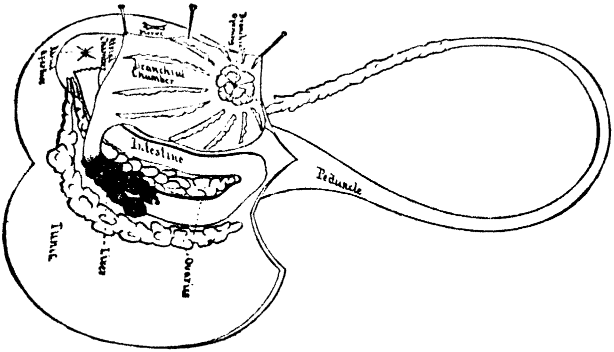


Fig. 136.—Anatomy of Boltenia.—Drawn by J. S. Kingsley from the author's dissections.

corresponding to the numerous branchial slits in the other Ascidians, but in Appendicularia each oral aperture leads into a funnel-shaped *atrial canal*, the open end of which terminates beside the rectum.

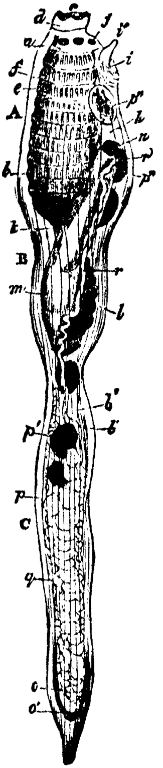


Fig. 137. — Structure of a compound Ascidian, *Amarœcium*. A, branchial sac; *m*, stomach; *k*, intestine; *c*, mouth; *o'*, testis; *r r'*, efferent duct of the testis; C, ovary; *p'*, egg in the body-cavity; *p''*, eggs in the atrium; *n*, anus; *o*, shows the site of the heart; *l*, liver; *e*, openings in walls of branchial chamber. —From Macalister.

The heart is a large pulsatile sac situated between the two lobes of the stomach. The nervous system is much more fully developed than in other Tunicates, and is constructed on the true Vermian type, consisting first of a ganglion situated below the mouth on the side opposite the atrial opening and opposite the anterior end of the endostyle. This nerve-centre throws off nerves to the sides of the mouth, and from it posteriorly extends a long cord past the œsophagus to the base of the tail, thence it extends along one side of the axis of the tail (urochord), swelling at regular intervals into small ganglia, from which from two to five small nerves radiate. On the cephalic ganglion a round ear-vesicle is attached. Behind the posterior turn of the digestive canal is the testis and ovary, the Appendicularia being hermaphrodite, as Fol claims, though the ovary is developed later than the testis. The Appendicularia has no test, but secretes a fibrous envelope, which is at first gelatinous, loosely surrounding the whole body, and allowing the creature the freest motion within its cavity.

The general structure of an Ascidian may perhaps be more readily comprehended by a study of a compound Ascidian (*Amarœcium*), which grows in white or flesh-colored masses on sea-weeds, etc. On removing an *Amarœcium* from the mass and placing it under the microscope, its structure can be perceived. The body is long and slender, as seen in Fig. 137. The mouth leads by the capacious branchial sac (A) to the stomach, while the intestine (B) is flexed, directed upwards, ending at the bottom of the atrium not far from the atrial opening. The reproductive glands are situated behind or below the bend of the intestine, the eggs being fertilized as they pass into the atrium, and the heart lies in the bottom of the body-cavity, being directly opposed to the nerve-ganglion (not represented in the figure), which lies between the two openings.

In the perfectly transparent *Perophora*, which grows on the piles of wharves on the coast of Southern New England, one individual after another buds out (as also in *Clavellina*) from a common creeping stalk like a stolon. In this form the circulation of the blood-disks in the branchial vessels and the action of the heart can be studied by placing living animals in glasses under the microscope. The heart is a straight tube, open at each end, and situated close to the hinder end of the branchial sac. After beating for a number of times, throwing the blood with its corpuscles in one direction, the beatings or contractions are regularly reversed and the blood forced in an opposite direction.

Renal organs are apparently represented in *Phallusia* by a peculiar tissue, consisting of innumerable spherical sacs containing a yellow concretionary matter. In *Molgula* and *Ascidia vitrea* Van Beneden, an oval sac containing concretions of uric acid lies close to the ovary.

In the forms already considered the plan of structure is complicated, owing to the difficulty of distinguishing an anterior or posterior, a dorsal or ventral aspect of the animal. In *Salpa* and *Doliolum*, however, the body is more or less barrel-shaped, the hoops of the barrel represented by the muscular bands which, at regular intervals, surround the body. The mouth is near the centre of the front end, the pharyngeal sac is very large, and the digestive tract makes less of a turn than in the ordinary Ascidians, while the atrial opening lies directly at the posterior opening. The heart is truly a dorsal vessel, and the nervous ganglion is situated on the opposite side of the body. This relation of the anatomical systems is most clearly shown in the genus *Doliolum*, and we have here a slight approach to the symmetrical relation of parts seen in the true worms, and which strongly suggest the conclusion that the Tunicates are modified worms. This conclusion is strengthened by the fact that in *Appendicularia* the ventral nervous cord is ganglionated at intervals, as in the Annelids, while the twisted digestive tract is much as seen in *Polyzoa* and Brachiopods. Furthermore, the branchial sac is strongly analogous to the pharyngeal or gill-sac of *Balanoglossus*, and this structure in the Ascidian and whale's-tongue worm anticipates the pharyngeal or gill-sac of *Amphioxus* and vertebrate embryos.

The simple Ascidians attain to a large size, *Ascidia callosa* being about ten centimetres in diameter, quite round, and in form and color bears a strong resemblance to a potato. *Ascidia gigas*, dredged by the Challenger Expedition, is from thirty to forty centimetres in diameter, and has a ganglion nearly as large as a pea. A floating colony of *Pyrosoma gigas* is sometimes five feet long. *Cynthia pyriformis* Rathke may be called the sea-peach, from its size, form, and the rich bloom and reddish tints of its test. It is common in deep water from Cape Cod to Greenland and Scandinavia.

While the Ascidians as a rule do not live below a depth of 150 fathoms, the stalked *Hypobythius calycodes* Moseley was dredged by the Challenger Expedition in 2900 fathoms in the North Pacific Ocean; it is stalked, and about twenty inches high. The aberrant *Octacnemus bythius* Moseley was also dredged in 1070 fathoms near the Schouten Islands, Tasmania.

Panceri has described the luminous organs of *Pyrosoma*, which is highly phosphorescent; the substance from which the light is emitted is probably a fatty matter.

Ascidians multiply by budding and by eggs. Examples of budding or germination are seen in the compound or social Ascidians, such as *Amaræcium*, etc., where the individuals of the colony bud out from the primitive one just as it has left the larval condition and has become fixed. In *Didemnium* buds arise from masses of cells floating free within the test. They multiply by division as soon as the digestive and reproductive organs are indicated. In *Botryllus* the zooid which results from the tadpole-like larva serves, according to

Huxley, merely as a kind of stalk, from which new zooids bud out, and this process, in his opinion, "leads to the still more singular process of development in *Pyrosoma*, in which the first formed embryo attains only an imperfect development, and disappears after having given rise to four ascidiozooids." In *Clavellina* and *Perophora* the original parent Ascidian throws off branches or stolons from which develop new individuals.

The usual mode of development in the simple and compound Ascidians (forming the order *Ascidiacea*) is by fertilized eggs. We will give the life-history of an Ascidian as based on Kowalevsky and Kupffer's researches on *Phallusia mammillata* Cuvier, in which the embryonic stages were observed, and *Ascidia intestinalis*, in which the larval and subsequent stages were studied.

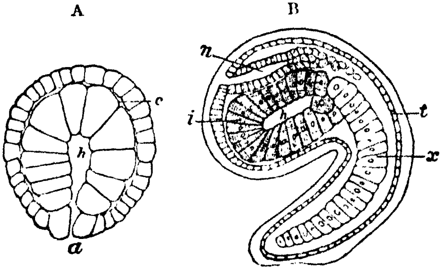


Fig. 138.—Embryo Ascidian. A, *a*, primitive opening; *h*, primitive digestive cavity; *c*, segmentation-cavity or primitive body-cavity; B, *i*, pharynx; *n*, nerve-cavity; *t*, epithelium forming the body-wall; *x*, rudimentary notochord.—After Kowalevsky.

The egg consists of a yolk unprotected by a yolk-skin, but surrounded by a layer of jelly containing yellow cells. The yolk undergoes total segmentation. The next step is the invagination of the ectoderm, a true gastrula state resulting. Fig. 138, *A* (after Kowalevsky), represents the gastrula; *h*, the primitive digestive cavity; *a*, the primitive opening, which soon closes; and *c*, the segmentation-cavity or primitive body-cavity. After this primitive opening (*a*) is lost to view, sometime before the embryo has reached the stage *B*, another cavity (*n*) appears with an external opening. This cavity is formed by a union of two ridges which grow out from the upper part of the germ. This is the central nervous system, and in the cavity are subsequently developed the sense organs. We thus see, says Kowalevsky, a complete analogy in the mode of origin of the nervous system of the Ascidians to that of the vertebrates, the nervous cavity, where the embryo is seen in section, being situated above the digestive cavity in both types of animals.

The next important stage is the formation of the tail. The pear-shaped germ elongates and contracts posteriorly until of the form indicated at Fig. 138, *B*. At this period appears the axial string of nucleated cells, called the *chorda dorsalis*, as it is homologous with that organ in *Amphioxus* and the embryo of higher vertebrates. The nervous system consists of a mass of cells extending halfway into the tail and directly overlying the *chorda*, but extending far beyond the end of the latter as seen in the figure. The nerve-cavity (*B*, *n*) after closing up forms the nerve-vesicle, a large cavity (Fig. 139, *a*), in which the supposed auditory organ (*e*) and the supposed eye (*a*) arise; this cavity finally closes, and the sense-organs are indicated by certain small masses of pigment cells in the fully grown Ascidian larva.

As the embryo matures, the first change observed in the cord is the appearance of small, refractive bodies between the cells. Between the neighboring cells soon appear in the middle minute highly refractive corpuscles which increase in size, and press the cell-contents out of the middle of the cord. After each reproductive corpuscle grows so that the central substance of the cell is forced out, it unites with the others, and then arises in the middle of the simple cellular cord a string of bodies of a firm gelatinous substance which forms the support of the tail. After this coalescence the substance develops farther and presses out the protoplasm of the cells entirely to the periphery. The cord when complete consists of a firm gelatinous substance surrounded by a cellular sheath which is formed of the remains of the cells originally comprising the rudimentary cord. The cells lying under the epithelial layer form a muscular sheath of which the cord (Fig. 138, *c*) is the support or skeleton.

The alimentary cavity arises from the primitive cavity

(Fig. 138, *A*, *h*); whether the primitive opening (Fig. 138, *A*, *a*) is closed or not, Kowalevsky says is an interesting question. According to analogy with many other animals it probably closes.

The larva hatches in from forty-eight to sixty hours after the beginning of segmentation, and is then of the form indicated by Fig. 139 (copied with some additions and omissions from Kupffer's figure, being partly diagrammatic). This anatomist discovered in the larva of *Ascidia canina*, which is more transparent than Kowalevsky's Phallusia larva, not only a central nervous cord overlying the *chorda dorsalis* and extending well into the tail, while in the body of the larva it becomes broader, club-shaped, and surrounds the sensitive cavity (*a*), but he also detected three pairs of spinal nerves (*s*) arising at regular intervals from the spinal cord (*h*, *h'*) and distributed to the muscles (not represented in the figure) of the tail; Kupffer calls *f* the middle and *g* the lower brain-ganglion. The pharynx (*b*), or respiratory sac, is now very large; it opens posteriorly into the stomach and intestine (*i*); *x* represents one of the three appendages by which the larva fastens itself to some object when about to change into the adult,

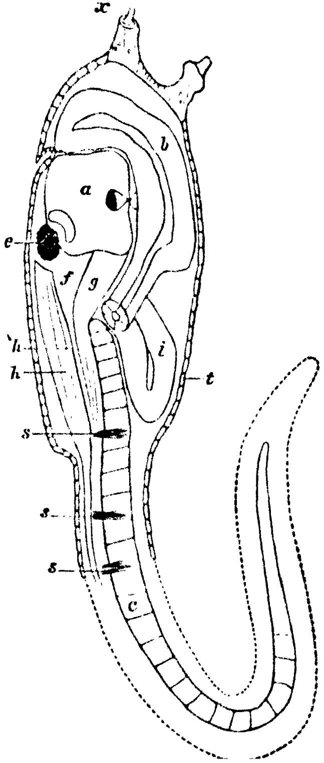


Fig. 139.—Larval Ascidian. *a*, sense cavity containing the eye; *b*, pharynx or respiratory sac; *c*, notochord; *e*, supposed auditory organ; *f*, middle, *g*, lower brain-ganglion; *h*, *h*, spinal cord; *s*, *s*, *s*, three sets of spinal nerves; *i*, intestine; *t*, body-wall, consisting of epithelial cells.—Copied with some changes from Kupffer.

sessile condition; *t* indicates the body-wall, consisting of epithelial cells.

We will now, from the facts afforded us by Kowalevsky, trace the changes from the larval, free-swimming state to the sessile adult Ascidia, which may be observed on the New England coast in August. After the larva fastens itself by the three processes to some object, the *chorda dorsalis* breaks and bends, the cells forming the sheath surrounding the broken axial cord. The muscular fibres degenerate into round cells and fill the space between the chorda and the tegument, the jelly-like substance forming a series of wrinkles. With the contraction and disappearance of the tail begins that of the nerve-vesicle, and soon no cavity is left. The three processes disappear; the pharynx becomes quadrangular; and the stomach and intestine are developed, being bent under the intestine. A mass of cells arises on the anterior end beneath the digestive tract, from which originate the heart and pericardium. In a more advanced stage, two gill-holes appear in the pharynx, and subsequently two more slits, and about this time the ovary and testis appear at the bottom, beyond the bend of the alimentary canal. The free cells in the body-cavity are transformed into blood-cells, and indeed the greater part of those which composed the nervous system of the larva are transformed into blood-corpuscles. Of the embryonal nervous system there remains a very small ganglion, no new one being formed. The adult Ascidian form meanwhile has been attained, and the very small individuals differ for the most part only in size from those which are full-sized and mature.

It will be seen that some highly important features, recalling vertebrate characteristics, have occurred at different periods in the life of the embryo Ascidian. Kowalevsky remarks that "the first indication of the germ, the direct passage of the segmentation cells into the cells of the embryo, the formation of the segmentation-cavity, the conversion of this cavity into the body-cavity, and the formation of the digestive cavity through invagination—these are all occurrences which are common to many animals, and have been observed in *Amphioxus, Sagitta, Phoronis, Echinus,* etc. The first point of difference from other animals in the development of all vertebrates is seen in the formation of the dorsal ridges, and their closing to form a nerve-canal. This mode of formation of the nervous system is characteristic of the vertebrates alone, except the Ascidians. Another primary character allying the Ascidians to the vertebrates, is the presence of a *chorda dorsalis*, first seen in the adult Appendicularia by J. Müller. This organ is regarded by Kowalevsky to be functionally, as well as genetically, identical with that of Amphioxus. This was a startling conclusion, and stimulated Professor Kupffer, of Kiel, to study the embryology of the Ascidians anew. He did so, and the results this careful observer obtained led him to fully endorse the conclusions reached by Kowalevsky, particularly those regarding the unexpected relations of the Ascidians to the vertebrates, and it would appear from the facts set forth by these eminent observers, as well as Metschnikoff, Ganin, Ussow, and others, that the vertebrates have probably descended from some type of worm resembling larval Ascidians more perhaps than any other vermian type, though it is to be remembered that certain tailed larval Distomæ appear to possess an organ resembling a *chorda dorsalis*, and farther investigation on other types of worms may lead to discoveries throwing more light on this intricate subject of the ancestry of the vertebrates. At any rate, it is among the lower worms, if anywhere, that we are to look for the ancestors of the Vertebrates, as the Cœlenterates, Echinoderms, the Mollusks, Crustacea and Insects, are too circumscribed and specialized groups to afford any but characters of analogy rather than affinity.

For example, the cuttlefish, with its "bone," brain-capsule and highly-developed eye, is, on the whole, more remote from the lowest vertebrate, *Amphioxus*, than the *Appendicularia* or the larval Ascidian.

Certain (three) species of *Molgula* have been found by Lacaze-Duthiers to have a nearly direct development, not producing tailed young. There is a slight metamorphosis, however, the young having five temporary, long, slender processes. In *Ascidia ampulloides* the larva has a tail, notochord and pigment spots, which are wanting in the young of several species of *Molgula*, but it has the five long deciduous appendages observed in young *Molgulæ*. Among the compound Ascidians, *Botryllus* and *Botrylloides* have tailed young, while in other forms there is no metamorphosis, development being direct.

Order 2. *Thaliacea.*—On the whole, we may regard this order, represented by *Salpa* (Fig. 140), and *Doliolum*, as comprising the more specialized forms of Tunicates. Salpa is pelagic, one species occurring in abundance off the shores of Southern New England, while the others mostly live on the high seas all over the tropical and subtropical regions of the globe. Late in the summer our *Salpa spinosa* of Otto can be captured in multitudes by the tow-net in Long Island Sound.

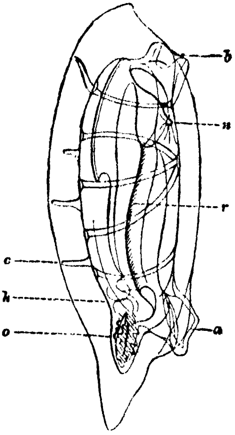


Fig. 140.—*Salpa spinosa*. An individual from a mature chain; three-quarter view, enlarged. *a*, atrial opening; *b*, mouth; *c*, processes by which the members of the chain are united; *h*, heart; *n*, nervous ganglion; *o*, nucleus; *r*, gill.—After A. Agassiz, from Verrill's Report.

There are in Salpa two kinds of individuals, *i.e.*, the solitary, and aggregated or chain-Salpæ. The body of the solitary or asexual form is more or less barrel-shaped, with a series of circular bands of muscles, like the hoops of a barrel, and situated on the inner side of the outer tunic. The test is transparent, though very thick, while the outer tunic lines the cavity of the test as in other Tunicates. In the members of this order the oral aperture of the mantle is at one end of the body, and the atrial opening at the opposite end, the minute digestive canal being but slightly curved, the body-cavity being largely occupied by the pharyngeal or respiratory sac. Moreover, the dorsal or hæmal side of the body is clearly distinguishable from the ventral or neural side, as well seen in *Doliolum*, where the well-marked tubular heart lies above the digestive organs, and is directly opposed, as in worms generally, to the nervous system, which is situated ventrally between the mouth and vent. We thus have in these Tunicates a front and hind end of the body, a dorsal and ventral, as well as a distinct bilateral symmetry of the body. This is seen in *Appendicularia* as well as in *Doliolum* and *Salpa*, however much this symmetry may be obscured in the more typical Ascidians, such as *Ascidia, Molgula, Boltenia*, etc.

The oral aperture leading into the respiratory sac is large, being as wide as the body ; the respiratory sac is more complicated than in other Ascidians, and more so than in *Doliolum*, where it is a wide, deep passage, the œsophagus at the hinder end, the sac itself perforated by two rows of branchial slits, four or five slits in each row. In *Salpa*, however, the respiratory sac, as described by Brooks, is attached to the outer tunic, around the edges of the mouth, as in other Tunicates. There are only two branchial slits, one on each side ; these are very large, and cover almost the whole surface of the branchial sac, except the median dorsal and hæmal lines. On the neural side the branchial slit opens directly into the atrium, the ciliated line where the two tunics unite being marked by the so-called "gill" (Brooks). In Salpa, according to Brooks, the branchial sac, though ciliated within, is not so directly concerned in the respiratory act as in other Tunicates, since respiration is effected largely by the action of the muscles, which also assist deglutition, and are the organs of locomotion. These contract rythmically, with great regularity, and at each contraction the water is expelled from the branchial sac through the atrial aperture ; and when the muscles are relaxed, the elasticity of the test distends the chamber, and a fresh supply is drawn in through the branchial aperture, the lips of which readily admit its passage in this direction, while a similar set of valves allows its passage out of the atrial aperture, but prevents its return." Thus a chain of individuals move with a uniform motion, while the solitary individuals and those which have been set free by the breaking up of a chain, move by jerks.

The digestive canal is small, curved on itself, the *œsophagus* leading from the bottom of the pharyngeal or respiratory sac into a small stomach, the intestine bending back on itself, and the vent being near the mouth. The entire digestive canal is immovable, the food being driven through the permanently distended cavity by means of the cilia lining its inner surface. The great posterior blood-sinus surrounds the digestive system on all sides, the nutriment being directly absorbed from its surface and mixed with the blood.

The nervous system is, in adaptation to its locomotive life, more specialized than in the sessile forms, and highly specialized organs of sight and hearing are present. The heart is a short, complicated organ, lying in the sinus-system. Its action is often reversed; the reversal of the beats tending to clear the sinuses of the blood-disks overcrowding them. In one species of Salpa Prof. Brooks states that the blood-channels are in all cases sinuses, which are parts of the body-cavity and have no special walls, though in species investigated by other writers there are said to be true blood-vessels, lined with epithelium.

The hermaphroditic, aggregated or chain-salpa differs from the solitary asexual form in being less regularly barrel-shaped, and without the two long posterior appendages of the latter; in the proportions of the different organs, the two forms are essentially alike.

The young chain is easily perceived in the solitary individuals in the posterior part of the body, curving around the digestive organs. When first set free from the body of the solitary Salpa, the chain is about half an inch long, and the single, individual Salpæ composing it are about two and a half millimetres in length. They grow very rapidly, and soon reach their full size, when the chains are often a foot or a foot and a half long; the individuals composing them when fully grown being about two centimetres in length. The chain easily falls apart, and the individuals are capable of living a solitary life, Huxley stating that the chain-individuals of the species observed by him were generally found solitary; for this reason we should regard the chain-salpæ as *individuals*, not *zooids*, being capable of leading an independent existence, and with a structure almost identical with that of the solitary Salpæ.

Brooks has studied the mode of development of the female and male *Salpa spinosa* (Fig. 140). When a Salpa-chain is discharged from the body of the asexual Salpa, each individual of the chain contains a single egg which is fertilized by sperm-cells of individuals belonging to some other chain, and after passing through the mulberry stage and entering the gastrula stage, the germ is in most intimate relation with the body of its parent. The vase-shaped gastrula is lodged in a brood-sac. Its body-cavity, originally formed by invagination of the ectoderm, opens directly into the sinus-system of its nurse, and the blood now circulates in and out of the primitive digestive cavity as well as around the outside of the embryo. But as the embryo grows and fills the brood-sac, so that the outer surface of the gastrula becomes intimately connected with the wall of the brood-sac, the blood no longer bathes the outside of the embryo.

At this time the "placenta" is formed. Brooks believes that it originates directly from the blood, "by the aggregation and fusion of its corpuscles," not being derived from any of the parts of the parent or embryo. Soon after its appearance it consists of an inner chamber communicating with the sinus of the nurse, and having no communication with any of the cavities of the embryo; its cavity being a part of the original "primitive stomach" of the gastrula. It finally has two chambers, an inner and outer one, and Huxley describes* the fœtal circulation in the placenta, a deciduous organ analogous in function, but by no means homologous in structure, with the vertebrate placenta.

When the embryo of the solitary Salpa is about four millimetres ($\frac{1}{30}$ inch) long, and while still in the brood-sac of the parent, the tube which is to give rise to the chain ap-

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* "The blood-corpuscles of the parent may be readily traced entering the inner sac on one side of the partition, coursing round it, and finally re-entering the parental circulation on the other side of the partition; while the fœtal blood-corpuscles, of a different size from those of the parent, enter the outer sac, circulate round it at a different rate, and leave it to enter into the general circulation of the dorsal sinus. More obvious still does the independence of the two circulations become when the circulation of either mother or fœtus is reversed."

By the deepening of these constrictions, each of the sinus-chambers, which are diverticula from the body-cavity of the solitary Salpa, becomes divided up to form the body-cavities of the Salpæ on one side of the chain. From the central tube of the stolon arises a row of buds on each side, which become the branchial and digestive organs of the Salpæ on each side of the chain ; while a similar double row, upon the other edge, gives rise to the ganglia. The club-shaped organs within the sinus-chambers become divided up into single rows of eggs, one of which passes into the body-cavity of each chain-salpa at a very early period of development.

Thus, as Huxley states, budding occurs, not from the outer wall alone, as in Hydroids and Polyzoa, "but, from the first, several components, derived from as many distinct parts of the parental organism, are distinguishable in it, and each component is the source of certain parts of the new being, and of these only." Prof. Brooks adds that while these changes are going on the constrictions on the surface deepen, the wall protruding from them, and each is soon seen to mark off, on each side of the stolon, the body of a young Salpa, which soon becomes visible to the naked eye. They do not increase in size gradually from one end of the stolon or tube to the other, but develop in sets of from thirty to fifty each, and the development of all which are embraced within a set progresses uniformly; there are usually three of these sets upon the tube of an adult solitary Salpa.*

Thus the Salpa reproduces parthenogenetically as in some Crustacea and insects, and we have here a true case of "alternation of generations." In 1819 Chamisso stated "that a Salpa mother is not like its daughter or its own mother, but resembles its sister, its granddaughter, and its grandmother.†

Immediately after the publication of Brooks' researches on *Salpa spinosa*, those of Salensky on *Salpa democratica-mucronata* (a species said to be closely allied if not identical with *S. spinosa*) appeared. According to the Russian observer, as stated by Huxley, who adopts his conclusions, the chain-salpa is a hermaphrodite, and the egg while still in the ovarian follicle is fertilized, when the oviduct shortening and widening forms a single uterine sac, the maternal and embryonic parts of the placenta arising, respectively, from the wall of the ovarian sac and from certain large cells (blastomeres) on the adjacent (hæmal) face of the embryo. Thus the asexual development of the Salpa is like that of the germ-masses destined to form the *Cercariæ* developed in the body of the *Redia* of the *Distoma;* and is also like that of the plant lice (Huxley). This is a reaffirmation and extension of the original view of Chamisso.

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* The Development of Salpa, by W. K. Brooks. Bulletin of the Museum of Comparative Zoology, III., No. 14, Cambridge, 1876. We have presented quite fully the author's account of the mode of development of the young asexual (his female) Salpa, without, however, adopting his interpretation of the sexes of the two kinds of individuals of Salpa; believing his "female" Salpa to be asexual, and his "male" Salpa to be hermaphrodite, with an ovary and testis, as he has not apparently observed the fact of the introduction of an egg into the body of his "male" Salpa. On the contrary, it appears to be developed originally in a true, simple ovary or "ovarian follicle;" the testis being immature and the egg fertilized by sperm-cells of other hermaphrodites, in-and-in breeding thus being prevented.

† This view has been endorsed by Steenstrup, Sars, Krohn, and others, especially by Leuckart in the following words quoted by Brooks: "It is now a settled fact that the reproductive organs are found only in the aggregated individuals of Salpa, while the solitary individuals, which are produced from the fertilized eggs, have, in place of sexual organs, a bud-stolon, and reproduce in the asexual manner exclusively, by the formation of buds. Male and female organs are, so far as we yet know, united in the Salpæ in one individual. *The Salpæ are hermaphrodite.*" On the other hand, Todaro, in an elaborate memoir (1876), considers the Salpa as the synthetic type of all the vertebrata, presenting features peculiar to each class, even including the mammals. In his opinion it is an allantoidian vertebrate, developed in a true uterus, the neck of which, after the life of the embryo begins, becomes plugged with mucus.

To recapitulate, the life-history of the Salpa is as follows: There are two kinds of individuals: *a*, solitary, asexual; *b*, social, aggregated, and hermaphroditic.

(1.) The solitary, asexual Salpa produces by budding a chain of hermaphrodite Salpæ; the latter produce a fertilized

(2.) Egg, which passes through a—

(3.) Morula and—

(4.) Gastrula stage, contained and growing in a placenta-like organ, where the embryo is directly nourished by the blood of the parent, the embryo finally becoming—

(5.) A solitary asexual Salpa.

We thus have a true alternation of generations, like the sexless Hydroid and its sexual Medusa, the asexual *Aphis* and its last brood of males and females; the asexual *Redia* and the sexual *Distoma;* in all these cases the offspring (*b*) of the asexual individual (*a*) is unlike the parent, but the offspring (*c*) of the second generation (*b*) is like (*a*) the grandparent.

Lastly, while some true worms (e.g., *Balanoglossus*), and the mollusks through the cuttle-fish, present strong features anticipating the vertebrate structure, the Tunicata seem more closely allied to the vertebrates, particularly *Amphioxus*, than any other invertebrate type. To sum up these resemblances: the larval Ascidian has a notochord, a spinal nerve-cord, and sets of spinal nerves, like those of lowly organized or embryonic vertebrates, though these are morphologically on the ventral side of the body, as in other worms; the nervous cavity and its mode of closure in the embryo is as in the embryo vertebrate; the respiratory sac of the adult Tunicate resembles morphologically that of the *Amphioxus*. Consequently, while as a matter of fact the Tunicates, as a whole, resemble, and as it were anticipate, the advent of a vertebrate, like Amphioxus; as a matter of pure hypothesis, the Vertebrates may have descended from animals *like* Tunicates. But we need not on this account dissociate the Tunicates from the worms, remembering their resemblance to *Balanoglossus*, and even to the Trematodes, and place them near *Amphioxus* and the Vertebrates in general. But we are obliged to leave them at this point and pass on to the consideration of the highly specialized worms and Mollusca, Crustacea, and Insecta, which are circumscribed, closed types of animals with possibly a vermian ancestry.

CLASS VI.—TUNICATA.

Body usually subspherical, or sac-like, obscurely symmetrical; sometimes barrel-shaped, bilateral, with a dorsal and ventral symmetry, protected by a transparent or dense test, containing cellulose, lined within by a tunic surrounding the body-cavity. Two openings in the test, one oral, the other atrial; mouth leading into a capacious pharyngeal respiratory sac, opening posteriorly by an œsophagus into a stomach, which is provided with a liver; intestine flexed, vent opening near the œsophagus, the fæces passing into an atrium or cloacal space, and thence out of the atrial opening. Nervous system bilateral, forming a double gangliolated chain (Appendicularia), but usually reduced to a single ganglion, situated within the tunic between the two openings; a tubular heart, opening at each end, lodged in a sinus-system, and its beatings often reversed, the blood flowing in and out at either end. Sexes usually united; in some forms asexual individuals; reproducing by eggs or budding parthenogenetically, or by gemmation.

Order 1. *Ascidiacea.*—Body sac-like, subspherical, usually sometimes stalked, simple or compound, minute individuals growing in a common mass; the oral and atrial openings contiguous; often a complete metamorphosis. (Appendicularia, Botryllus, Amarœcium, Clavellina, Perophora, Ascidia, Boltenia, Pyrosoma).

Order 2. *Thaliacea.*—Body barrel-shaped; free-swimming, test thick, hyaline; with circular muscular bands; respiratory sac widely open; reproducing by alternation of generations. (Salpa, Doliolum).

***Laboratory Work.*—The Tunicates can well be studied only in a living state; or sections of hardened Salpæ may be made. The young, caught with the tow-net, should be immediately examined, as they are very short-lived. Delicate sections of hardened eggs and larvæ are made with great difficulty, but are necessary to examine in connection with the living more or less transparent animals.**

CLASS VII.—NEMERTINA (*Nemertean Worms*).

General Characters of Nemerteans.—The Nemertean worms occur abundantly under stones, etc., between tide-marks and below low-water mark; they are of various colors, dull red, dull green and yellowish, and are distinguished by the soft, very extensile, more or less flattened, long and slender body, which is soft and ciliated over the surface, the skin being thick and glandular. A few forms, such as *Prorhynchus* (Fig. 141), live in fresh water.

The mouth forms a small slit on the ventral surface immediately behind the aperture for the exit of the proboscis. The œsophagus leads to a large digestive tract, ending posteriorly with an anus, and often with short lateral cœca. In *Pelagonemertes* and *Avenardia* the numerous cœca are much branched.

The nervous system is quite simple, consisting of two ganglia in the head united by a double commissure; from each ganglion a thread composed of nerve fibres and ganglion cells passes back to the end of the body.

While the Nemerteans are much like the flat worms, most of them approach the *Annulata*, such as the earthworm, in their highly complicated circulatory system, which is composed of a series of closed contractile vessels. There are three great longitudinal trunks, one median and two lateral, and connecting with each other. The blood is pale, rarely red, with corpuscles. Another feature characteristic of many Nemerteans is the "proboscis," nothing like it being found in other worms. Along the back of the head-end is a special muscular sheath containing the complicated proboscis, which is extended through a pore situated above the mouth. The sheath contains a corpusculated fluid, and both the sheath and proboscis lie between the commissures of the ganglia in the front part of the head.

The ovaries and testes are situated in sacs on each side of the digestive canal. The sexes are distinct, with the exception of certain species of *Borlasia*. The breeding season is from March to April, while others spawn all summer. The eggs are ejected from lateral, pale, minute openings, and the species may be either oviparous or ovoviviparous. These worms when molested often break into fragments; in such cases each piece is capable of reproducing the entire animal and all its internal organs.

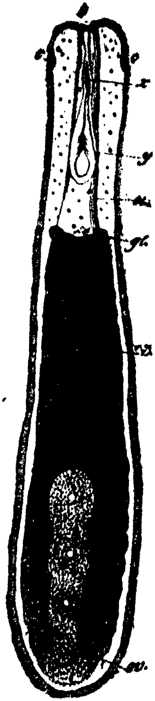

Fig. 141. — *Prorhynchus fluviatilis*, one of the simplest Nemertean worms. *o*, mouth; *œ*, œsophagus; *i*, intestine; *gl*, glands opening into the intestine; *c*, ciliated pits; *x*, style in the proboscis situated above the œsophagus, which ends in a blind sac at *y*; *ov*, ovary, with eggs in different stages of development. The worm is externally ciliated.—After Gegenbaur.

The Nemerteans present a great range of variation in their mode of development. In the simplest mode of growth the young is a ciliated oval form, without any body-cavity. In others there is a body-cavity, but the larva is minute and ciliated, and attains the adult form by direct growth. In still another species (*Nemertes communis*) the embryo is a ciliated gastrula, but leaves the egg in the adult form. In others there is a complete and most interesting metamorphosis. In several Nemertean worms the egg undergoes total segmentation, leaving a segmentation-cavity. The next occurrence is the separation of a one-layered ciliated blastoderm, the ectoderm, which invaginates, forming the primitive digestive cavity, from which the stomach and œsophagus are formed. The larva (originally described under the name of *Pilidium*) is now helmet-shaped, ciliated, with a long lash (flagellum) attached to the posterior end of the body. (Fig. 142.)

After swimming about on the surface of the sea a while, the *Nemertes* begins to grow out from near the œsophagus of the Pilidium. On each side of the base of the velum (*v*) of the Pilidium appear two thickenings of the skin, one pair in front, the other behind; these thickenings push inwards, and are the germs of the anterior and posterior end of the future worm. The anterior pair become larger than the posterior; the part of the disk next to the œsophagus thickens; at the same time the alimentary canal of the Pilidium grows smaller, and only a narrow slit remains. The disks now divide into two layers, the outer much thicker than the inner. Soon the anterior pair of disks unite, and the head of the worm is soon formed, when the elliptical outline of the flat worm is indicated, and appears somewhat as in Fig. 142. The yolk mass, with the alimentary canal of the Pilidium, is taken bodily into the interior of the Nemertes, the Pilidium-skin falls off, and the worm finally seeks the bottom.

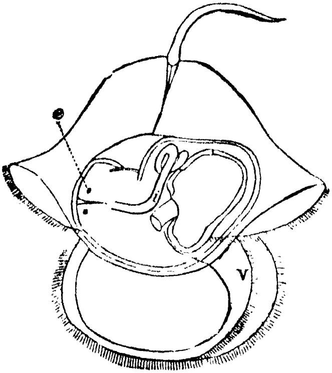

Fig. 142.—Larva or "Pilidium" of Nemertes, with the worm growing in it. *v*, velum; *e*, eyes; *i*, intestine of the Nemertean worm.—**After Leuckart.**

The free-swimming larvæ of other Nemerteans are very closely similar to those of the Annelids, so that from this fact and the nature of the highly developed circulatory system, the Nemerteans have been removed from the neighborhood of the flat worms, and placed near the *Balanoglossus* and *Gephyrea*, as well as the leeches.

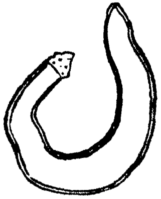

Fig. 143. — *Tetrastemma*, a Nemertean worm; magnified.

Order 1. *Anopla.*—In this group the proboscis is without a style. The species of *Lineus* and *Meckelia* are, in some cases, very long. *Meckelia ingens* Leidy is 2½ centimetres (an inch) wide, and attains a length of 4 metres (15¼ feet). It lives under stones at or below low-water mark on the coast of New England southwards to South Carolina.

Order 2. *Enopla.*—In the members of this group the proboscis is furnished with a style. Representatives of the order are the species of *Tetrastemma* (*T. serpentinum* Girard, Fig. 143) and of *Nemertes*. The former is a little yellowish worm, common under stones on the coast of New England between high and low-water mark; it has a slightly marked head with four dark eye-specks.

CLASS VII.—NEMERTINA.

Body ribbon-like or cylindrical, soft, extensible, ciliated externally, with a proboscis in a sheath opening by a pore situated above the mouth. Circulatory system approaching that of the Annulata. Sexual organs, ductless sacs; either with or without a metamorphosis.

Order 1. *Anopla.*—Proboscis without a style. (Lineus, Meckelia.)

Order 2. *Enopla.*—Proboscis with a style. (Nemertes, Malacobdella.)

CLASS VIII.—ENTEROPNEUSTA (*Acorn-tongue worms.*)

General Characters of the Enteropneusta.—The remarkable worm, *Balanoglossus* (Fig. 144), the type of this class, combines characters peculiar to itself, with features reminding us of the Nemerteans, Annelids, Tunicata, and even the vertebrate *Amphioxus*, while its free-swimming larva, before its history was known, was supposed to be a young Echinoderm. It is therefore, like some other worms, a synthetic or generalized type.

Balanoglossus aurantiacus (Girard, Fig. 144) is a long, cylindrical, soft, fleshy worm, footless, without bristles, but with a large, soft, whitish tongue-shaped proboscis in front, arising dorsally within the edge of the collar surrounding the mouth. At the beginning of the digestive canal is a series of sac-like folds, of which the upper or dorsal portion is respiratory, and separated by a constriction from the lower, which is digestive, and leads directly to the intestine behind. This pharyngeal respiratory portion of the digestive canal has on each side, in each segment, a dorsal sac, the two communicating along the median line of the body. The dorsal respiratory sacs bear in their walls a delicate chitinous gill-support or arch. Between the gill-arches, forming numerous lamellæ, are a series of slits, leading on each side to openings (spiracula) situated dorsally. The water passes through the mouth into each gill-sac, and out by the spiracles. No nervous system has yet been discovered. There is a dorsal vessel, which sends branches to the respiratory sacs, and a ventral vessel. The worm lives in sand at low-water mark from Cape Ann to Charleston, S. C.

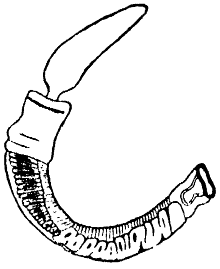

FIG. 144.

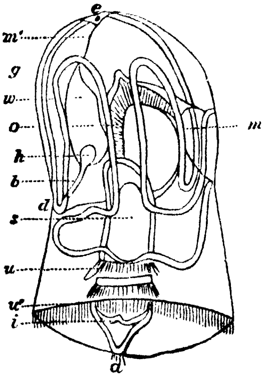

FIG. 145.

Fig. 143.—*Balanoglossus*, not fully mature; magnified.

Fig. 144.—Larva (*Tornaria*) of *Balanoglossus*. *a*, anus; *b*, branch of water-vascular system leading to the dorsal pore (*d*); *e*, eye-speck; *g*, gills; *h*, heart; *i*, intestine; *m*, mouth; *m'*, muscular band from the eye to the water-vascular tube; *o*, œsophagus; *s*, stomach or alimentary canal; *u*, lappet of stomach; *u'*, anal band of cilia; *w*, water-system.—After A. Agassiz.

The life-history of this worm is most interesting. The young, originally described under the name of *Tornaria*, was supposed to be an Echinoderm larva, though it closely resembles the larval *Gephyrea* and *Annelides*. It is a transparent, minute, ciliated, slender, somewhat bell-shaped form (Fig. 145), with black eye-specks. When transforming to the worm condition, a pair of gills arise on sac-like outgrowths of the œsophagus, and afterwards three additional pairs with their external slits arise, somewhat as in Ascidians. The entire Tornaria directly transforms into the worm, the transitional period being very short. The body lengthens, the collar and proboscis develop, and the worm eventually is as seen in Fig. 144; afterwards the body lengthens, the end tapering and becoming much coiled.

CLASS VIII.—ENTEROPNEUSTA.

Footless, smooth-bodied worms; with no bristles, a large exserted soft fleshy proboscis; breathing by a series of dorsal respiratory sacs opening into the digestive canal, and communicating externally by spiracles; with a metamorphosis. (Balanoglossus.)

CLASS IX.—GEPHYREA (*Star-worms*).

General Characters of the Gephyreans.—The most accessible type or representative of this small but interesting group of worms is a large, smooth, cylindrical worm from six to ten inches long, which is common in sand or sandy mud at low-water mark. It is the Sipunculus or *Phascolosoma Gouldii* Diesing, and from its abundance and large size, as well as the ease with which it can be preserved in spirits, is an excellent subject for the laboratory, serving as an example of a very aberrant type of worm as compared with the earthworm, or with a *Nereis*. The body is as smooth as a pipestem, and about that size, unarmed, with a circle of numerous small, flat, foliaceous tentacles around the mouth. On laying open the body from the head to the extremity (Fig. 146), the body-walls are seen to be lined with fine longitudinal flat muscles, with two unequal pairs of large white retractor muscles, the anterior third of the body being highly retractile. The intestinal part is found to float freely, though anteriorly attached to the walls by a few muscular threads, in the capacious body-cavity, and is usually full of fine mud. The œsophagus is long and slender, situated between the shorter pair of retractor muscles; behind the insertion of the muscles it enlarges, but there is no true stomach; it is about twice the length of the body, and is bent and twisted on itself, ending dorsally in a vent marked by an external wart, on the anterior third of the body. Near this point is situated a pair of large, long, slightly twisted segmental organs(*s*)the free ends of which flare slightly. The nervous system (*n*) forms an œsophageal ring, and from it passes a well-marked ventral single cord, from which at short intervals pass off small short lateral nerves. The vascular system is represented by a circular vessel lying next to the nervous œsophageal ring, sending branches into, or at least in communication with, the cavities of the tentacles, and from the ring passing along and intimately connected with the digestive tract, forming a ruffle-like organ (*v*), ending at a point nearly opposite the vent (*a*). Prof. Greef finds that the vascular system of *Echiurus* consists of two main vessels, *i. e.*, a dorsal and a ventral vessel; the former extending along the alimentary canal, and sending a branch to the proboscis, where it divides into two branches, each uniting with the ventral vessel. The blood is pale yellowish, with corpuscles. The blood-system of the Gephyrea, then, is homologous with

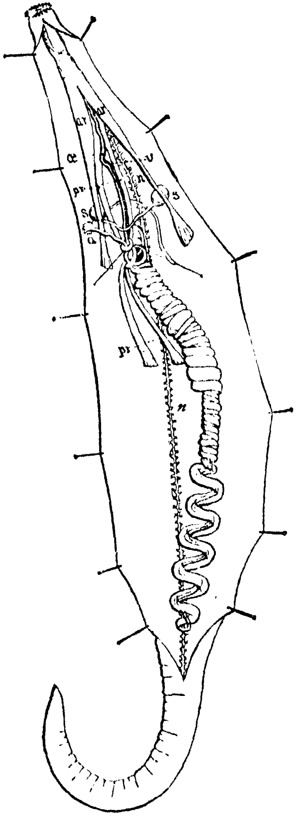

Fig. 146.—Anatomy of *Phascolosoma Gouldii*, cut open, with the flaps pinned down. *æ*, œsophagus; *ar*, two short muscles; *pr*, two long retractor muscles, *c*, next to a dark line the right side of the long œsophagus indicating the water-vascular tube; *n*, nervous cord; *s*, segmental organs; the long, twisted intestine returns, ending at *a*. Natural size.—Drawn by J. S. Kingsley.

that of the *Annulata.* There is in *Phascolosoma* no true ovary, but the eggs float in masses in the capacious body-cavity, the animal being a hermaphrodite.

Phoronis is from the highly developed crown of long, slender tentacles, and its complicated blood-system, remarkably like the *Serpulæ,* with which Annelids it is by some authors associated. The alimentary tube, however, is like that of *Phascolosoma,* the intestine folded and ending next to the mouth. No nervous system has been detected. A pulsating artery is attached to the upper side of the long œsophagus, and its branches go into the tentacles from an œsophageal ring. "Two venous trunks open from the sinuses above and behind the arterial branches, and then proceed downwards, half encircling the œsophagus, till they unite in a large vessel on its neural surface." (Dyster.) This worm is minute, about four millimetres in length, and lives in a tube buried in holes in rocks. It has a strong resemblance to a Polyzoon, but connects the Gephyrea with the true Annelids.

In the Sipunculus-like worm *Phascolosoma,* and in *Phoronis,* there is a well-marked metamorphosis, and the larvæ are somewhat like those of Annelids. The larva of *Phascolosoma* is cylindrical, the head small, with a circle of cilia, but there are no arms as in the larva of the *Phoronis.*

The earliest observed stage of *Phoronis** is a free-swimming larva, the body transparent, ciliated, with an umbrella-like expansion on the head, covering the region of the mouth, while the end of the body is truncated. At this stage it is a true *Cephalula,* like that of Echinoderms and worms. Afterwards four projections arise at the end of the body, and twelve long, arm-like projections grow out, the larval form now being fully attained. In this condition it was described as a mature animal under the name *Actinotrocha.*

When the Actinotrocha is about to transform into a *Phoronis* the end of the intestine bends up, opening outward near the mouth. The umbrella is gradually withdrawn into the mouth, so that eventually only a crown of short tooth-like projections surrounds the mouth. Finally the whole umbrella is swallowed, the arms at the end of the body disappearing, while the end of the intestine projects far out from the body behind the mouth. By this time the *Phoronis* form is clearly indicated, the body being long and slender and the mouth surrounded by a crown of short tentacles, the end of the intestine being entirely withdrawn within the body. These changes are rapidly effected. The larva of *Echiurus* is formed on the Annelid type.

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* In our Outlines of Comparative Embryology this account of the metamorphosis of *Phoronis* is by mistake regarded as descriptive of Sipunculus on pp. 157, 158, under *Development.* The word Phoronis on those pages should be substituted for Sipunculus.

In *Phascolosoma cœmentarium* (Quatrefages), the body is much shorter than in *P. Gouldii*; the worm lives in comparatively deep water (10 to 50 fathoms), in dead, deserted shells, building out the aperture by a conical tube of sand. In *Sipunculus* (Syrinx) the tentacles are fringed or lobed. It does not occur in American waters.

In *Echiurus* the intestine ends at the end of the body, and there is a circle of bristles at the posterior end, while *Bonellia* differs in having an enormous proboscis, and only a few bristles near the head. In *Bonellia viridis* Rol. of the Mediterranean (Fig. 147), the proboscis is deeply forked; the intestine is very long, convoluted, and into the cloaca empty two excretory organs. The ovary is a cord-like organ, which in the posterior part of the body is fastened to the intestine.

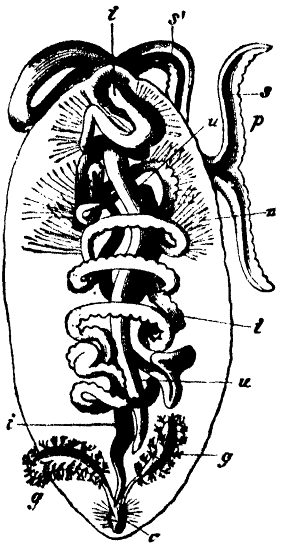

Fig. 147.—*Bonellia viridis*; the proboscis coiled several times. *p*, fore end of the proboscis; *s*, *s'*, furrow in the proboscis; *i*, *i*, digestive canal; *m*, mesenterial threads (only shown on the anterior end of the digestive canal); *g*, organs of excretion; *c*, cloaca; *u*, oviduct.—After Lacaze-Duthiers; from Gegenbaur.

Chætoderma nitidulum Lovén occurs in 20–40 fathoms off the coast of Europe and Northern New England. The body is long, cylindrical, and covered with slender, firm, calcareous spines. It has no tentacles, a straight digestive canal, the vent being terminal, and two internal gill-sacs, with external lamellate gills.

Instead of a single nervous cord, as usual in the *Gephyrea*, in *Chætoderma* there are two separate nerve-cords, one on each side of the body. The Gephyrea were formerly associated with the Echinoderms, but the resemblance is only a superficial one.

CLASS IX.—GEPHYREA.

Body long, cylindrical, smooth, or spiny, or provided with bristles, not segmented; usually a large proboscis, but none in Phascolosoma; vent either terminal or situated dorsally on the anterior end of the body. A true blood-system homologous with that of the Annulata. Bisexual or hermaphroditic; young of the Annelid type, undergoing a metamorphosis. (Chætoderma, Phascolosoma, Sipunculus, Bonellia, Echiurus, and Phoronis.)

Laboratory Work.—The common star-worm, *Phascolosoma*, is one of the easiest worms to dissect, as it can be readily laid open with the scissors, and the skin pinned down on the bottom of the dissecting trough, when the parts can be readily distinguished, its structure being unusually simple.

CLASS X.—ANNULATA (*Leeches, Earth-worms, and Sea-worms*).

General Characters of the Annulata.—This group, represented by the leeches, earth-worms, and nereids or bristled sea-worms, tops the series of the classes of worms, and in the highly specialized, regularly segmented bodies, with their sense-organs and highly differentiated appendages, stand nearer the Crustacea and Insecta than any other class of invertebrate animals, their internal organization on the whole being nearly as complicated.

Reference to the accompanying diagram (Fig. 148) will show the general relation of the organs of an Annelid to the body-walls, as compared with corresponding parts, when seen in sections of Amphioxus and a fish.

The student, in familiarizing himself with the structure and mode of growth of the leech, the common earth-worm and the Nereis, will obtain a good idea of the essential characteristics of the entire class.

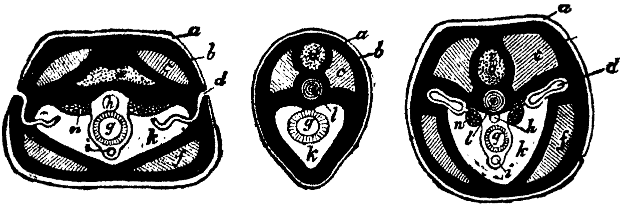

Fig. 148.—Transverse section of a worm, of Amphioxus, and a higher vertebrate contrasted. *a*, skin; *b*, dermal connective layer; *c*, muscles; *d*, segmental organ; *h*, arterial, and *i*, venous blood-vessel; *g*, intestine; *l*, notochord.—After Haeckel.

Order 1. *Hirudinea.*—In the leech (Fig. 149), *Hirudo medicinalis* Linn., the type of the first and lower order, the body is somewhat flattened and divided into numerous short, indistinctly marked segments, not bearing any bristles or appendages. The head is small, with no appendages, bearing five pairs of simple eyes, while each end of the body terminates in a sucker. The mouth is armed internally with three pharyngeal teeth arranged in a triradial manner, so that the wound made in the flesh of persons to whom the leech is applied consists of three short, deep gashes radiating from a common centre. The stomach (Fig. 150) is large, with large lateral diverticula or lobes, while the intestine is small. The nervous system consists of a "brain" and ventral ganglionated cord.

The vascular system is complicated, consisting of a median dorsal and a ventral vessel, and two lateral vessels; all these anastomose or interbranch, and the blood which courses through them is red, but is said to contain no corpuscles.

The segmental organs, so characteristic of the *Annulata*, are well developed in the leech, consisting of about seventeen pairs of tubes opening at one end at regular intervals on the under side of the body, and ending in a non-ciliated coil (Fig. 149, *r*) in the leech, or in the smaller fish-leech, *Clepsine*, open into the venous sinus by ciliated, open mouths.

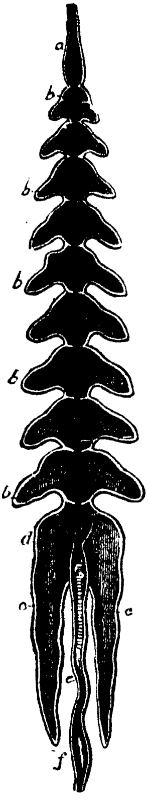

FIG. 150.

Fig. 149.—Anatomy of the medicinal leech; opened from below. *a*, *h*, buccal sucker; *b*, infra-œsophageal ganglion; *e*, *e*, *e*, ventral ganglia; *d*, last ganglion; *f*, *f*, *f*, commissures joining the ganglia; *g*, *g*, *g*, nerves of sense and locomotion; *i*, œsophagus; *k*, *k*, *k*, *k*, the dilatations or cœca of the stomach; *m*, the last of these lobes or cœca; *p*, *p*, intestine lying, as well as the stomach, above the nervous chain; *q*, rectum; *r*, *r*, *r*, segmental organs; *s*, pouch; *x*, sheath of *z*, coupling organ; *t*, right epididymis; *A*, *A*, *A*, spermatic cords; *B*, *B*, *B*, testes; *D*, matrix; *E*, *E*, ovaries; *w*, end of oviduct; *v*, sucker.

Fig. 150.—Digestive canal of the same; *a*, *b*, *b*, *b*, *b*, the stomach and its lateral lobes or cœca; *d*, *c*, the two large cœca which extend along each side of the intestine *e*, *e*; *f*, rectum.—After Gervais and Van Beneden.

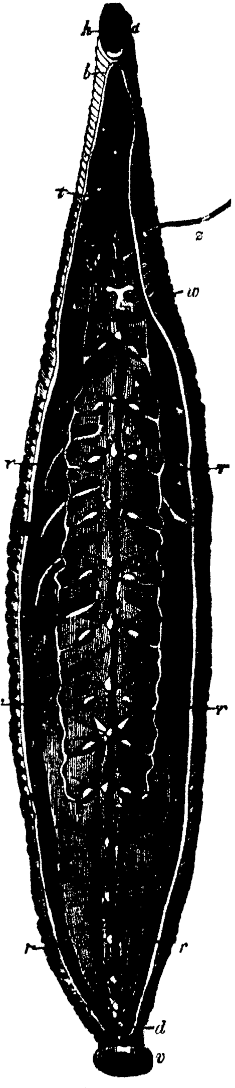

FIG. 149.

The leech is hermaphroditic, while in certain allied forms (*Histriobdella,* etc.) the sexes are distinct.

The eggs of leeches are laid in sacs, or, as in *Clepsine,* the fish-leech, are covered with a transparent fluid substance, which hardens and envelops the eggs. The *Clepsine* remains over the eggs to protect them until they hatch; and the young, after exclusion, fix themselves to the under side of the parent, and are thus borne about until they are fully developed and able to provide for themselves (Whitman*). The changes in the egg of *Clepsine,* after fertilization, are very complicated, and have been described by Whitman. The egg subdivides into a bilateral mass of cells called a *blastula;* † a gastrula, and finally a "neurula" stage, characterized by the formation of a "primitive band" like that of insect embryos. Soon after attaining the latter stage the embryo hatches and attaches itself to its parent. The mouth is then formed, the nervous system‡ arises from the ectoderm, the segments are indicated, the original number being thirty-three, the segmental organs develop from the mesoderm at about the time of hatching, and about six days after the neurula leaves the egg the eyes become visible. The innermost germ-layer (endoderm) does not arise until eight days after hatching, and by this time the digestive tract is perfected; the muscular walls of the alimentary canal being derived from the mesoderm.

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* The Embryology of Clepsine. By C. O. Whitman. Quarterly Journal of Microscopical Science. July, 1878.

† Whitman states that a *morula,* as defined by Haeckel, does not occur in the developmental history of *Clepsine,* and he states that when the cleavage process of the egg has been carefully studied it has been found to result in the production of a bilateral germ or *blastula,* and not a morula. "'A solid sphere of indifferent cells' is, to say the least, a very improbable form, so improbable that its existence may be held questionable until established by positive evidence. The doubt is all the more justifiable, as more careful investigation has in many cases already shown that the so-called *mulberry stage* is not a morula, but a blastula or even a gastrula." (Whitman.)

‡ There is originally a pair of ganglia in each of the thirty-three segments; four of these are consolidated into the subœsophageal ganglia, eight in the ganglia of the disk, and four in the terminal ganglia of the body. (Whitman.)

The early phases in the embryological development of the leech (*Clepsine*) strongly resemble those of corresponding stages in the vertebrates, according to a number of observers. The origin of the germ-bands, the presence of the primitive streak as well as the mode of cleavage, and the formation of the gastrula* and neurula, show that, up to a comparatively late period of embryonic life, some worms (Annulata) and the Vertebrates travel along the same developmental path. As observed by Whitman, the neurula of the chick, or of the fish, belongs to the same type as that of *Clepsine.* Whether the Vertebrates ever descended from the worms or any other type of Invertebrates or not, it is a matter of fact that there is an essential unity in organization and mode of early development in all the *Metazoa*, or three-germ-layered animals, and that the vertebrates are probably only a very highly specialized group of animals, a branch of the same genealogical tree from which have sprung the only less generalized groups or branches of *Mollusca*, *Annulata*, and *Arthropoda.* Certainly the division of the animal kingdom into Vertebrates and Invertebrates, however useful, is essentially artificial and misleading. Hence it follows that a study of the Annulata, as well as other types of worms, must prove to be fruitful in valuable results, and lead to what may seem startling conclusions.

Order 2. *Annelides.*—To this order belong the earthworm and sea-worms. The structure of the common earthworm (*Lumbricus terrestris* Linn., Fig. 151) is essentially like that of the leech. Externally the body is cylindrical, many-jointed, the joints or segments much more distinct than in the leech, and internally there are septa, or thin muscular partitions, between them. The mouth is small, forming an opening on the under side of the first segment. On, or next to, the twenty-ninth to the thirty-sixth segments in *Lumbricus terrestris* is a flesh-colored swollen portion called the *cingulum* or *clitellum.*

The earth-worm is able to climb perpendicularly up boards, etc., as well as over the ground, by minute, short, curved setæ or bristles, which are deeply inserted in the muscular walls of the body, and arranged in four rows along each side of the body. The alimentary canal is straight, the stomach has three pairs of small lateral blind sacs (cœca), and the intestine, which is externally tubular, contains a thick internal sac-like fold called a *typhlosole.*

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* **Professor His admits that the bird passes through a stage comparable with the gastrula of other animals. (Whitman, p. 94.)**

The segmental organs are highly convoluted tubes, a pair to each segment of the body, except a few near the head, and opening internally with ciliated funnels and externally in minute pores situated along the under side of the body. The earth-worm is monœcious (hermaphroditic).

The oviducts open in the fourteenth segment, and the seminal ducts (*vasa deferentia*) in the fifteenth. Between the ninth and tenth, and the tenth and eleventh segments are the four openings of the seminal receptacles (*receptacula seminis*). Pairing is reciprocal (see Fig. 151), each worm fertilizing the eggs of the other; they pair in June and July in the night-time. The eggs of the European *Lumbricus rubellus* Grube are laid in dung, a single egg in a capsule; *L. agricola* lays numerous egg-capsules, each containing sometimes as many as fifty eggs, though only three or four live to develop. The development of the earth-worm is like that of the leech, the germ passing through a morula (blastula), gastrula and neurula stage, the worm, when hatching, resembling the parent, except that the body is shorter and with a much less number of segments.

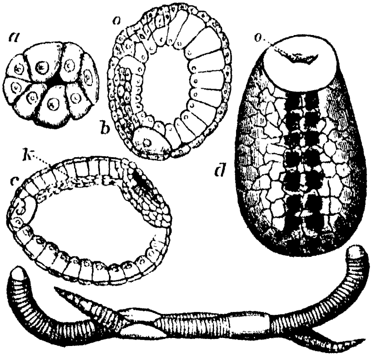


Fig. 151.—Earth-worms pairing. After Curtis. *a*, embryo (blastula) soon after segmentation of the yolk; *b*, embryo further advanced; *o*, mouth; *c*, embryo still older; *k*, primitive streak; *d*, neurula; *o*, its mouth.—After Kowalevsky.

While the earth-worms are in the main beneficial, from their habit of boring in the soil of gardens and ploughed lands, bringing the subsoil to the surface and allowing the air to get to the roots of plants, they occasionally injure young seedling cabbage, lettuce, beets, etc., drawing them during the night into their holes, or uprooting them.

The next and highest type of *Annulata* is the common sea-worm of our coast, *Nereis virens* Sars. It lives between tide-marks in holes in the mud, and can be readily obtained. The body, after the head, eyes, tentacles and bristle-bearing feet have been carefully studied, can be opened along the back by a pair of fine scissors and the dorsal and ventral red blood-vessels with their connecting branches observed, as well as the alimentary canal and the nervous system.

The anatomy of this worm has been described by Mr. F. M. Turnbull. It is very voracious, thrusting out its pharynx and seizing its prey with its two large pharyngeal teeth. It secretes a viscid fluid lining its hole, up which it moves, pushing itself along by its bristles and ligulæ. At night, probably during the breeding season, they leave their holes, swimming on the surface of the water.

The body consists of from one hundred to two hundred segments. The head consists of two segments, the anterior and buccal, the for- with four eyes two pairs of The second segment bears four antennæ (tentacular cirri). Each of the other segments bears a pair of paddle-like appendages (rami), which may be best studied by examining one of the middle segments which

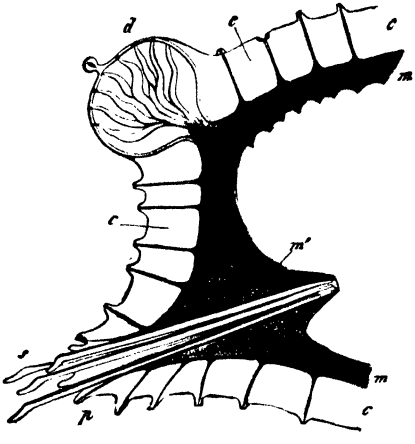


Fig. 152.—Vertical section through the integument of an Annelid (*Sphærodorum*). *c*, thick cuticular layer with the pore-canals; *m*, muscular layer; *m'*, muscles of the bristles, *s*, which retract the central foot-lobe, while others pass to its dorsal glandular projection, *d*.—After Gegenbaur.

has been separated from the others. For the finer structure of the body-walls see Fig. 152.

The alimentary canal consists of a mouth, a pharynx armed with two large teeth and much smaller ones. The pharynx is entirely everted during the act of taking its food. Into the œsophagus empty two large salivary glands; the remainder of the alimentary canal is straight and tubular. The circulatory system is very complicated; it is closed and the blood is red. Both the dorsal and ventral vessels are contractile, the blood flowing forward in the dorsal vessel. and backward in the ventral vessel. The two small vessels, one on each side, in each segment of the body, branch off from the ventral vessel and subdivide, each sending a branch to the ventral ramus of the foot of the segment behind, and another larger branch around the intestine to the dorsal vessel, receiving also, on its way, a vessel from the upper ramus of the foot of its own segment. "Besides these principal lateral vessels, there are five other vessels on each side in each segment, coming from the ventral vessel. These form a loose but regular net-work that surrounds the intestine and is connected with five other convoluted vessels, which join the dorsal vessel. This net-work on the intestine probably supplies the hepatic organ with material for its secretion, and very likely may receive nutritive material from the digested food." (Turnbull.)

The blood is aërated in the finer vessels of the oar-like feet and in those situated about the alimentary canal. The nervous system consists of the "brain" and ventral double ganglionated cord.

The sexes of *Nereis virens* are separate; the eggs during the breeding season fill the body-cavity, and pass out through certain of the segmental organs, which act as oviducts, while others, probably the more anterior ones, are excretory, like the kidneys of vertebrates, as urea has been detected in them. These organs are situated at the base of the lower ramus of each foot. In some species of the *Capitellidæ* Eisig has found that it is normal for several segmental organs to be present in a single segment.

While the mode of development of our Nereis has not been studied, the eggs are probably laid in masses between tide-marks, and the young, when hatched, swim freely on the surface of the sea. The eggs of other worms are carried about in lateral pouches. The germ undergoes a cleavage phase and a gastrula stage. We have observed, in Salem harbor, the development of *Polydora* (probably *P. ciliatum* Clap.) which may be found in August, in all stages, on the surface of the water. When first observed (Fig. 153, *A*) the body was spherical, with a short, broad intestine, and two sets of large locomotive bristles. It then passed into the cephalula state, the head clearly indicated and forming a large hood. This stage is seen at *B*, which represents the under side of the cephalula, the mouth being situated between the two large ciliated flaps (like the velum of larval mollusks) of the hood; the body is now segmented, with a third set of bristles and a band of cilia on the penultimate segment; afterwards as at *C*, dorsal view, additional rings are present; the eyes are distinguishable, and there are two more sets of bristles. The new segments are, as usual in all

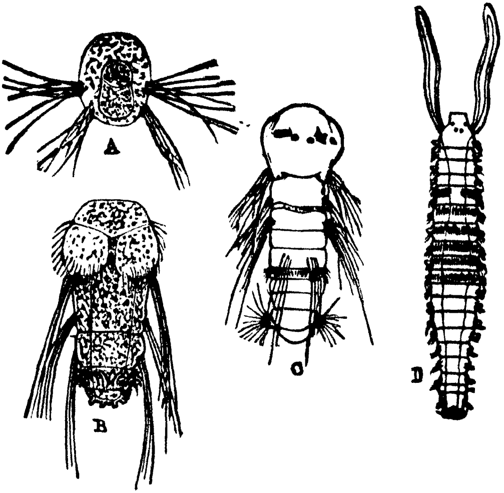


Fig. 153.—*A*, earliest observed stage of *Polydora*; *B*, Cephalula stage; *C* and *D*, later stages.—Author del.

articulates, interpolated between the penultimate and terminal segments of the body. At *D*, the body is many-jointed, the tentacles well developed, the large temporary bristles have been discarded, and the worm can be identified as a young *Polydora*.

It is probable that *Polydora* is hatched as a *trochosphere* like that of *Polyzoa, Brachiopoda* and certain mollusks. The young *Terebrellides Stroemii,* and of *Lumbriconereis,* are at first trochospheres, *i. e.*, the free-swimming germ is spherical, with a zone of cilia, two eye-spots, and no bristles. Thus the earliest stages of *Polyzoa, Brachiopoda, Lamellibranchiata, Gastropoda,* and even of a Cephalopod (Fig. 220), Nemertina, and Annelides are almost identical. Farther along in their developmental history, the cephalula of the Annelides (Fig. 153, *A*, *B*, and 155), is like that of certain Echinoderms (Fig. 155), *Gephyrea, Polyzoa, Brachiopoda,* and *Mollusca.* It may here be observed that the free-swimming larvæ of these types of invertebrate animals are the young of more or less sedentary parents. In this way the species becomes widely distributed through the action of the marine currents, and too close in-and-in breeding is prevented.

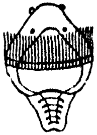


Fig. 154.—Larva of *Phyllodoce.*—After A. Agassiz.

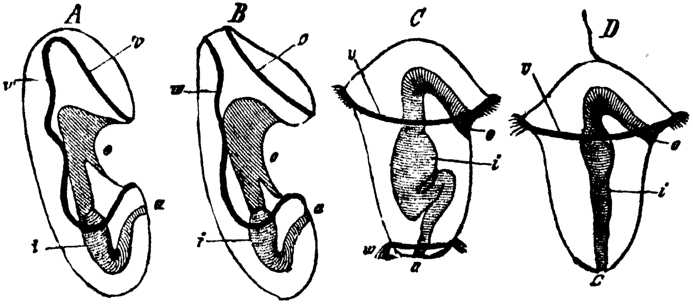


Fig. 155.—Cephalula stage of Echinoderms and Worms, lateral view. *A*, Holothurian, *B*, Star-fish, *C*, *D*, of Annelides.
o, mouth ; *i*, stomach ; *a*, vent ; *v*, præoral ciliated band, in *B*, *C*, *D*, independent ; in *A* surrounding an oral region.—From Gegenbaur.

Certain Annelides sometimes multiply by self-division, the process being called *strobilation.* This is commonly observed in the fresh-water worm *Nais*, also in *Syllis* and *Myrianida*, as well as in *Filograna*, *Protula*, etc. *Autolytus*, a common worm on the coast of New England, produces one generation by budding (parthenogenesis). There is, in fact, an alternation of generations, an asexual *Autolytus*, giving rise to a brood of males and females, the sexual and asexual forms being so unlike each other as to have been mistaken for different species and even genera.

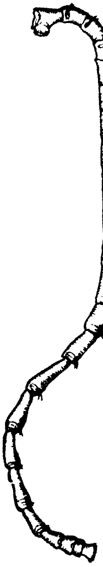


FIG. 156.

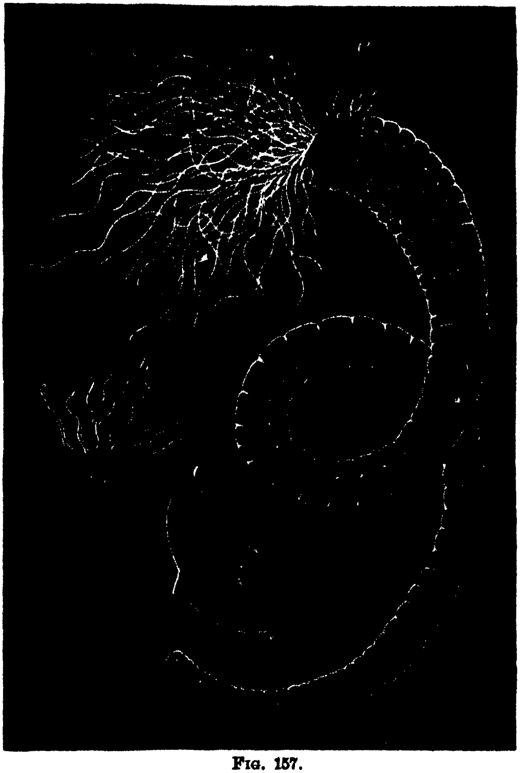


FIG. 157.

Fig. 156.—*Clymenella torquata.*—After Verrill.

Fig. 157.—*Amphitrite cirrata*, enlarged twice. *b*, branchia; *c*, uncini, enlarged 500 diameters.—After Malmgren.

In *Syllis* and allies certain long, slender processes of the feet are jointed, thus anticipating the jointed appendages of the Crustacea and Insects.

The Annelides are divided into two suborders. The first suborder, *Oligochæta,* comprises *Lumbricus, Nais,* etc., while the second suborder, *Chætopoda,* embraces *Syllis, Autolytus, Nereis, Polydora, Aphrodite,* and *Polynoë,* which are free-swimming, while the tubiculous worms which respire by special branchiæ, or gills, on the head, live in tubes of sand or in limestone shells. Those which live in sand or mud-tubes are *Cirratulus* (Fig. 160), *Clymene* and *Clymenella* (Fig. 156), which has no branchiæ, *Amphitrite* (Fig. 157), *Terebrella, Cistenides* (Fig. 158), *Sabella,* and *Euchone* (Fig. 159), while *Protula, Filograna, Serpula* and *Spirorbis* secrete more or less coiled limestone tubes. The large solid shells of the Serpulæ assist materially in building up coral reefs,

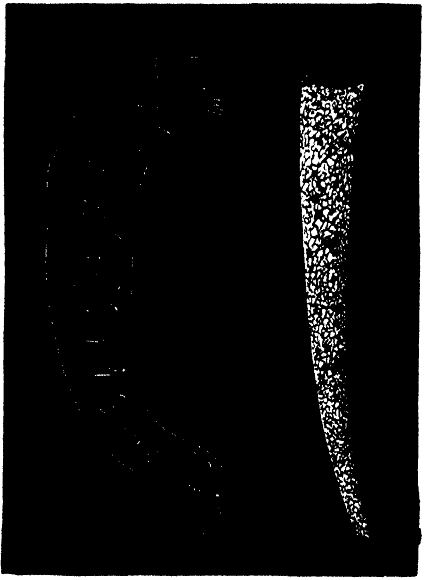


Fig. 158.

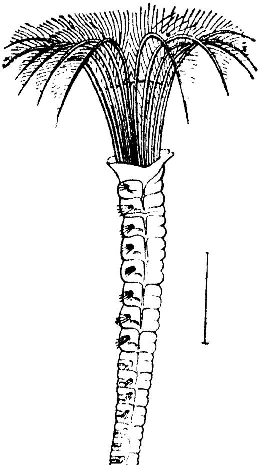


Fig. 159.

Fig. 158.—*Cistenides Gouldii,* and its tube.—After Verrill.
Fig. 159.—*Euchone elegans,* enlarged.—After Verrill.

especially on the coast of Brazil. The minute nautilus-like shells of Spirorbis live attached to the fronds of sea-weeds, especially the different kinds of Fucus.

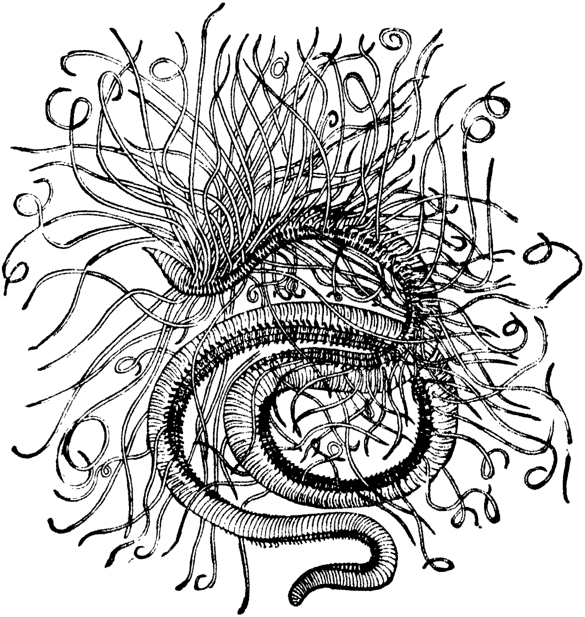


Fig. 160.—*Cirratulus grandis.*—After Verrill.

Many sea-worms are highly phosphorescent, the light emitted being intensely green. The tracks of worms like the Nereis of to-day occur in the lower Silurian slates; their bristles, however, were spinulose, as in the larval worms. Thus the type, though highly specialized, has, unlike most specialized groups, a high antiquity, the specialized *Annelides* existing side by side with the generalized *Polyzoa* and *Brachiopoda.* At the present time the *Annelides* are widely distributed in the seas of the globe, the tropical forms being exceedingly abundant among coral stocks and in sponges, while the arctic seas abound with Annelid life. They also sparingly exist at great depths, one species of a worm allied to *Clymene*, having been dredged by the Challenger Expedition at the enormous depth of over three miles (about 5000 metres).

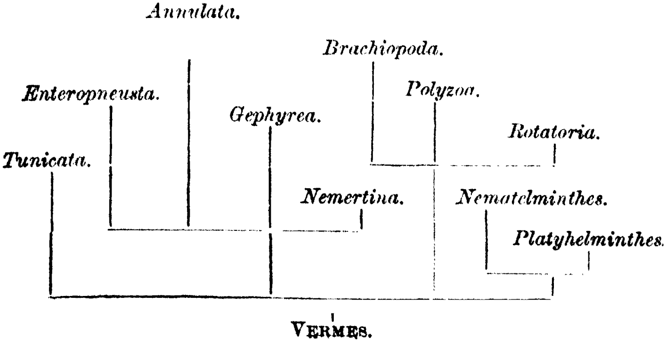
CLASS X.—ANNULATA.

Body long, bilaterally symmetrical, cylindrical, consisting of numerous segments, either unarmed, or more usually provided with setæ alone or with setæ and paddle like appendages (rami). Head simple, with a few simple eyes, or provided with tentacles (antennæ) alone, or with tentacles and branchiæ. An eversible pharynx, armed with teeth, usually present. Alimentary system straight, the tubular stomach sometimes sacculated; vent always situated in the last segment of the body. Nervous system well developed, consisting of a brain and ventral ganglionated cord. Circulatory system closed, with a dorsal and ventral and lateral vessels connected by anastomosing branches in nearly each segment. A system of numerous paired segmental organs. Sexes united or separate. Embryo passing through a cleavage-stage (morula or blastula), gastrula, sometimes a neurula stage, and after hatching, development is either direct or there is a marked metamorphosis, the larva passing through a trochosphere and cephalula stage.

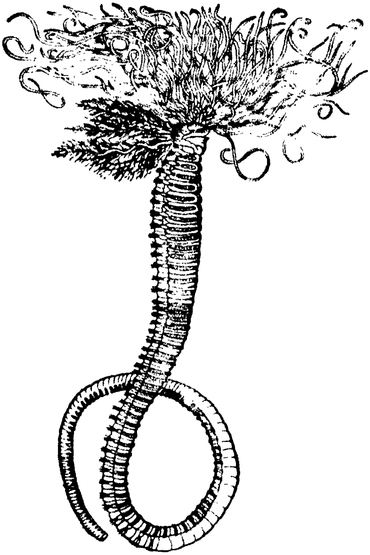
Order 1. *Hirudinea.*—Body unarmed, finely segmented; with a posterior sucker. (Hirudo, Nephelis.)

Order 2. *Annelides.*—Suborder 1. *Oligochæta* (Lumbricus, Nais). Suborder 2.—*Chætopoda* (Arenicola, Syllis, Autolytus, Aphrodite, Polynoë, Amphitrite, Terebrella, Sabella, Serpula, Spirorbis).

TABULAR VIEW OF THE CLASSES OF WORMS (VERMES).



Laboratory Work.—Worms should be dissected at once after being killed by ether or in alcohol, before the circulation has ceased; and transverse sections made to observe the relation of the appendages to the body-walls, and of the different systems within the body-walls. The worms should also be hardened in alcohol, and thin sections stained with carmine be made for histological study. A portion of the worm can be put in paraffine and sliced by hand with the razor or by the microtome.



Amphitrite ornata.

CHAPTER VI.

BRANCH VI.—MOLLUSCA.

General Characters of Mollusks.—The characters which separate this branch from the others, especially the *Vermes* are much less trenchant than those peculiar to other groups of the same rank, and indeed the author only retains the Mollusks as a special branch in deference to the general usage of zoologists, believing that the *Mollusca* are probably only a highly specialized group of *Vermes,* where they were originally placed by Linnæus, and bearing much the same relation to the true worms as do the *Rotatoria,* the *Tunicata,* the *Brachiopoda,* etc. It will be seen from the following account of the mollusks, that they travel along, apparently, the same developmental road as the genuine worms, and then suddenly diverge, and the divergence is not an advance in a parallel direction, but if anything the road turns back, or, to change the simile, the branch of the genealogical tree bends downwards. It is, and always has been, extremely difficult to define the *Mollusca,* their original bilateral symmetry being partially effaced in most of the *Gastropoda* and in some Lamellibranchs, *i. e.*, in those Gastropods with a spirally-twisted shell like the snail, or in fixed bivalve forms like the oyster, etc. The *Mollusca* are usually defined as animals with laterally symmetrical, unjointed bodies protected by a shell, with a foot or creeping disk, and usually with lamellate gills, which are folds of the mantle or body-walls. The special organs characterizing the Mollusks are the foot and, in nearly all except Lamellibranchs, the odontophore; but the foot of a snail is simply a modification of the under lip, and in reality in many forms but a specialized ventral surface, as is that of certain non-segmented worms, like the Planarians and Nemerteans; while the odontophore or lingual ribbon, often absent, is apparently a modification of the pharyngeal teeth of Annelides. Mollusks in general have a heart consisting of a ventricle and one or two auricles, and in this respect they are more like the Vertebrates than other invertebrated animals; the highly developed eye of the squids and their imperfect cartilaginous brain-box are also special characters analogous to the eye and brain-box of Vertebrates. Still these features are not homologous with the corresponding parts in the Vertebrates, and we have already seen that the *Tunicata*, and even the Annelides, are much more closely allied to the *Vertebrata* than are the Mollusks, which should, perhaps, be interpolated between the Brachiopods and Tunicates. The affinities of the Mollusks are, then, decidedly with the worms, rather than with the Vertebrates.

That the *Mollusca* are a highly specialized and comparatively modern group is shown by the fact that they began to abound after the Brachiopods had had their day in the Silurian seas, and had begun to decay and die out as a type; the shelled *Mollusca* supplanted the shelled Vermes or Brachiopods. For the upper Silurian period, and those later, the Mollusks prove useful as geological time-marks, especially in the Cainozoic period, and so much so that Lyell based his divisions of Tertiary time mainly on the shells which abound in Tertiary strata.

Although morphologically the shell of a Mollusk is not the most important feature of the animal, it is very characteristic of them and of great use in distinguishing the species of existing, but more especially of fossil, forms; still it is liable to great variation, and mollusks of quite different families, and even orders, sometimes have shells much alike, so that the characters of shells, like many of those drawn from the peripheral parts of the body, are liable oftentimes to mislead the student. That the *Mollusca* are a highly specialized group is also seen by the enormous number of existing species, and their wide geographical and bathymetrical range. There are about 20,000 living and 19,000 fossil species known, and the group ranks next to the winged insects, also a comparatively recent and highly specialized group, in the number of species and individuals.

CLASS I.—LAMELLIBRANCHIATA (*Acephala, Bivalves*).

General Characters of Lamellibranchs.—This group is represented by the oyster, clam, mussel, quohog, scallop, etc. By a study of the common clam (*Mya arenaria* Linn.) one can obtain a fair idea of the anatomy of the entire class, as it is a homogeneous and well-circumscribed group. The clam is entirely protected by a pair of solid limestone shells, connected by a hinge, consisting of a large tooth (in most the sandy bottom of the water, when the mussel is ploughing its way through the sand with its tongue-shaped foot, which is a muscular organ attached to the visceral mass, and is a modification of the under lip of the larval mollusk. In the foot is an orifice for the passage in and out of water, but the spurting of water from the clam's hole, observed in walking over the flats, is the stream ejected from the siphon. The inflowing currents of water pass from the inner end of the muscular siphon below the lenticular visceral mass to the mouth, which is situated at the anterior end of the shell, opposite the siphon. The opening is simple, unarmed, without lips, and often difficult to detect. On each side of the mouth is a pair of flat, narrow-pointed appendages called palpi. The digestive canal passes through a dark rounded mass, mostly consisting of the liver, covered externally by the ovarian

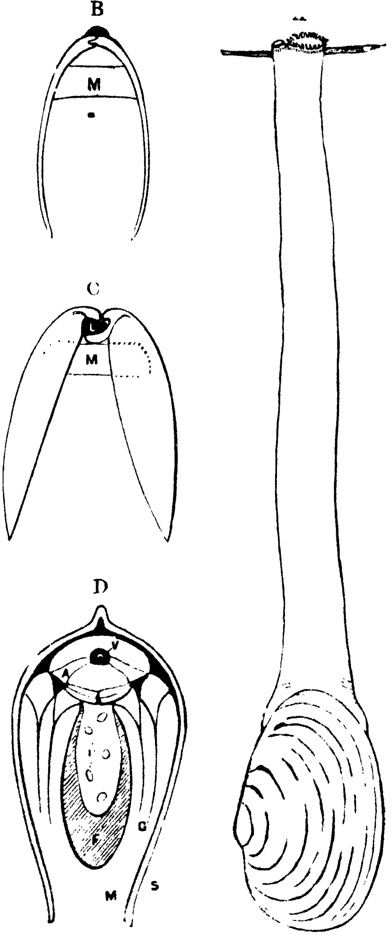


Fig. 161.—*A*, *Mya arenaria* with its siphons extended; in its natural position in the mud head-end downwards; *B*, transverse section of the shell, showing the position of the spring opening the shell; *M*, adductor muscle; the ligament represented by dark mass; *C*, section of Unio, showing the position of the spring to open the shell; *L*, ligament; *D*, ideal transverse section of Unio; *I*, intestine; *F*, foot; *V*, ventricle; *A*, auricle; *G*, gills; *M*, mantle; *S*, shell.—After Morse.

masses. There is no pharynx armed with teeth as in the *Cephalophora* and *Cephalopoda*, but the œsophagus leads to a tubular stomach and intestine, the latter loosely coiled several times and then passing straight backwards along the dorsal side under the hinge and directly through the ventricle of the heart, ending posteriorly opposite the excurrent division of the siphon. Through the visceral mass passes a curious slender cartilaginous rod, whose use is unknown, unless it be to support the voluminous viscera. The gills or branchiæ are four large, broad, leaf-like folds of the mantle, two on a side, hanging down and covering each side of the visceral mass (Fig. 161, D, G). The heart (Fig. 163) is contained in a delicate sac, called the pericardium, and is situated immediately under the hinge; it consists of a ventricle and two auricles; the former is easily recognized by the passage through it of the intestine (Fig. 161, D, V), usually colored dark, and by its pulsations. The two wing-like auricles are broad, somewhat trapezoidal in form. Just behind the ventricle is the so-called "aortic bulb." The arterial system is quite complicated, as is the system of venous sinuses, which can be best studied in carefully injected specimens. At the base of the gills, however, is the pair of large collective branchial veins. The kidney, or "organ of Bojanus," is a large dusky glandular mass (Fig. 164, 4) lying below but next

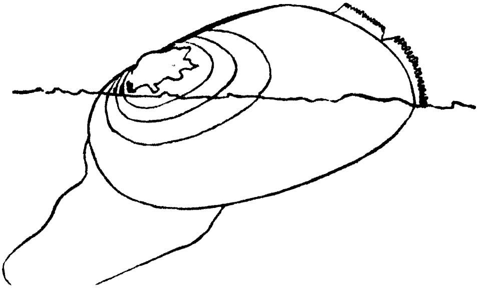


Fig. 162.—*Unio complanatus*, partly buried in the sand, the siphonal openings above the level of the river-bottom.—After Morse.

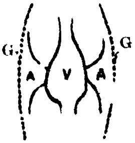


Fig. 163.—Heart of the clam. V, ventricle; A, auricles; G, base of gills.—After Morse.

to the heart; one end is secretory, lamellar and glandular, communicating with the pericardial cavity, while the other is excretory and opens into the cavity of the gill. The nervous system can be, with care and patience, worked out in the clam or fresh-water mussel. In the clam (*Mya arenaria*, Fig. 165) it consists of three pairs of small ganglia, one above (the "brain") and one below the œsophagus (the pedal ganglia) connected by a commissure, thus forming an œsophageal ring; and at the middle of the mantle, near the base of the gills, is a third pair of ganglia (parieto-splanchnic), from which nerves are sent to the gills and to each division of the siphon. This last pair of ganglia can be usually found with ease, without dissection, especially after the clam has been hardened in alcohol. The ear of the clam is situated in the so-called foot; it bears the name of *otocyst* (Fig. 166, *i*), and is connected with a nerve sent off from the pedal ganglion. It is a little white body found by laying open the fleshy foot through the middle. Microscopic examination shows that it is a sac lined by an epithelium, resting on a thin nervous layer supported by an external coat of connective tissue. From the epithelium spring long hairs; the sac contains fluid and a large otolith. The structure of this octocyst may be considered typical for Invertebrates.

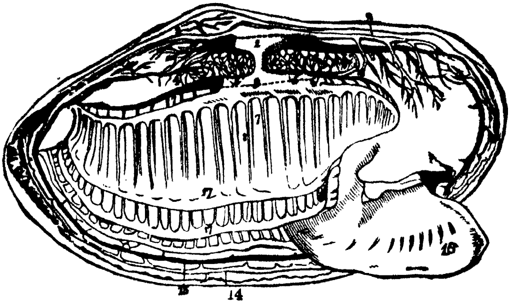


Fig. 164,—Circulatory system of *Anodonta*, a fresh-water mussel, after Bojanus. 1, ventricle; 2, arterial system; 14 and 15, veins which follow the border of the mantle. The veins lead the blood in part directly towards the organ 4, which is the kidney or "organ of Bojanus," and in part to the venous sinus of the upper surface of this organ; 5, veins which carry back the blood from the gills, the rest going to the sinus, 6, where arise the branchial arteries; 7, 8, the branchial veins, and 9, the gill.—From Gervais et Van Beneden.

The ovaries or testes, as the sex of the clam may be, are bilaterally symmetrical, blended with the wall of the visceral or liver-mass, and are yellowish. The genital openings are paired and lie near the base of the foot. Both eggs and semen arise from the epithelium of the sexual glands. The eggs pass out into the body-cavity, or accumulate between the

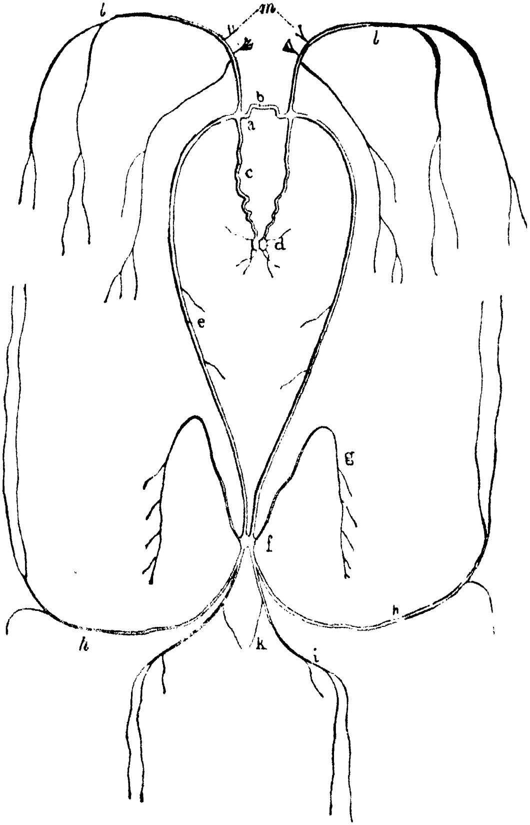


Fig. 165.—Nervous system of the clam, natural size. *a*, œsophageal ganglion; *b*, commissure anterior to the mouth; *c*, pedal commissure; *d*, pedal ganglia; *e*, parieto-splanchnic commissures; *f*, parieto-splanchnic ganglia; *g*, branchial nerves; *h*, *l*, pallial nerves; *i*, siphonal nerves; *k*, anal nerves; *m*, nerves to the anterior adductor.—Drawn by W. K. Brooks.

gills, where the embryos in some species partially develop. Impregnation probably takes place *within the branchial* chamber, the spermatozoa being swept in with the respiratory current, and coming in contact with the eggs as they are discharged.

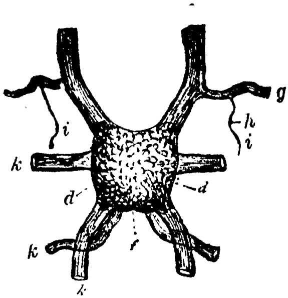


Fig. 166.—Pedal ganglia and otocysts (ears) of the clam, magnified 10 diameters. *d*, pedal ganglia; *e*, pedal commissures; *f*, line of union of ganglia; *g*, nerve from commissure to muscles of foot; *h*, auditory nerve; *i*, otocyst; *k*, nerves from ganglia to the pedal muscles.—Drawn by W. K. Brooks.

An excellent general view of the relation of parts to the body-walls and shell may be seen by hardening a clam, or better a fresh-water mussel, *Unio* (see Fig. 161, *D*) in alcohol, and then making transverse sections. A section can be floated off in water and examined with a lens. The perfect bilateral symmetry of parts will thus be seen.

The above description will answer for the majority of lamellibranchiate mollusks; in the oyster (*Ostræa*) or in *Ano-*

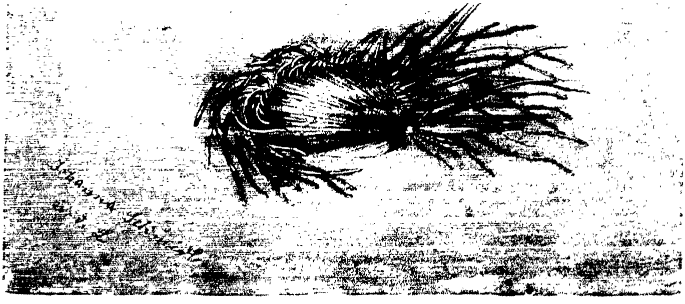


Fig. 167.—*Lima hians*, flying through the water, its long numerous filaments extended.—From Brehm's "Thierleben."

mia the shell is inequilateral, one, usually the lower, being fixed to some object, and the intestine does not pass through the ventricle; in *Arca* the ventricle is double. In *Lucina* and *Corbis* there is but one gill on each side, and in *Pecten, Spondylus* and *Trigonia* the gills are reduced to comb-like processes. There are usually no eyes present; in the scallop (*Pecten*), however, there is a row of bright shining eyes with tentacles along the edge of the mantle, and contrary to the habits of most bivalves, the scallop can skip over the surface of the water by violently opening and shutting its shell. *Trigonia* is also capable of leaping a short distance; while *Lima* (Fig. 167) is an active flyer or leaper. *Ostrea* and *Cyclas* are diœcious, while many mollusks are monœcious or hermaphroditic. The foot varies much in form, in the mussel (*Mytilus*, Figs. 168, 169), *Pinna*, *Cyclocardia* (*Cardita*) (Fig. 170), and the pearl-oyster it is finger-shaped and

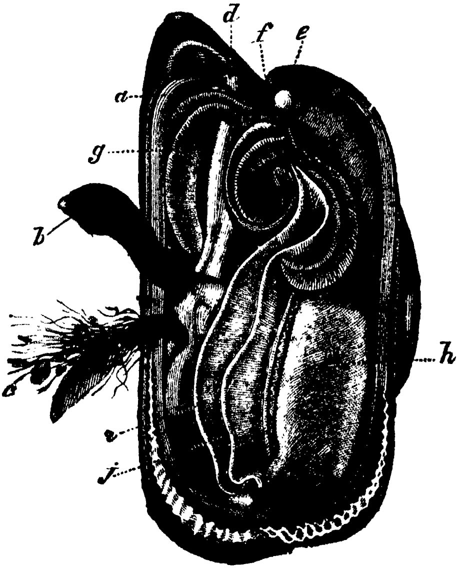


Fig. 168.—*Mytilis edulis*, common mussel. *a*, mantle; *b*, foot; *c*, byssus; *d* and *e*, muscles retracting the foot; *f*, mouth; *g*, palpi; *h*, visceral mass · *i*, inner gill; *j*, outer gill.—From Brehm's "Thierleben."

grooved, with a gland for secreting a bundle of threads, the *byssus*, by means of which it is anchored to the bottom.

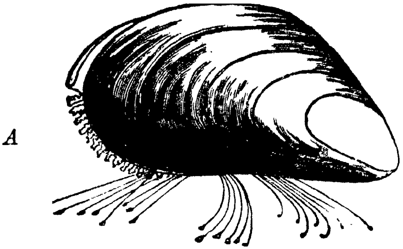


FIG. 169.

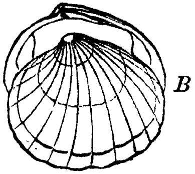


FIG. 170.

Fig. 169.—*Mytilus edulis*, common mussel, with its fringe expanded, and anchored by its byssus.—After Morse.
Fig. 170.—*Cyclocardia novangliæ*, natural size.—After Morse.

The foot in the quohog (Fig. 171 *A*, *Venus* *Mulinia* (171 *B*) and *Clidiophora* (Fig. 172) is large, these

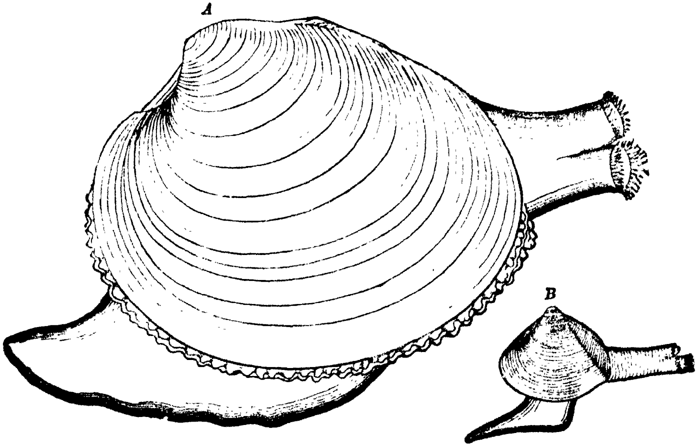


Fig. 171 *A*.—*Venus mercenaria*, quohog, natural size, with the foot and siphons.
Fig. 171 *B*.—*Mactra* (*Mulinia*) *lateralis*, natural size.—After Verrill.

mollusks being very active in their movements. In *Glycimeris* (Fig. 173) the fringe is toothless, much as in the oyster. In *Mactra* (Fig. 174) the middle tooth is large, the corresponding cavity large and triangular. In *Saxicava* and *Panopæa* (Fig. 175), the pallial line is represented by a row of dots. In *Macoma* (Fig. 176) the siphons are very long.

Lithodomus, the date shell, one of the mussels, bores into corals, oyster shells, etc.; the common *Saxicava* excavates holes in mud and soft limestone, as does *Gastrochæna*, *Pholas* and *Petricola*. Many boring Lamellibranchs are said to be luminous.

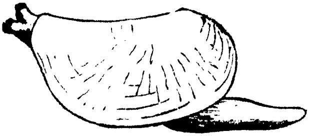


Fig. 172.—*Clidiophora trilineata*, natural size.—After Verrill.

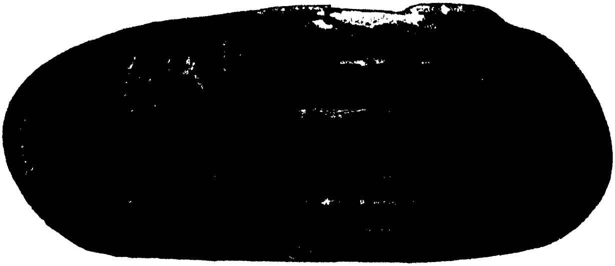
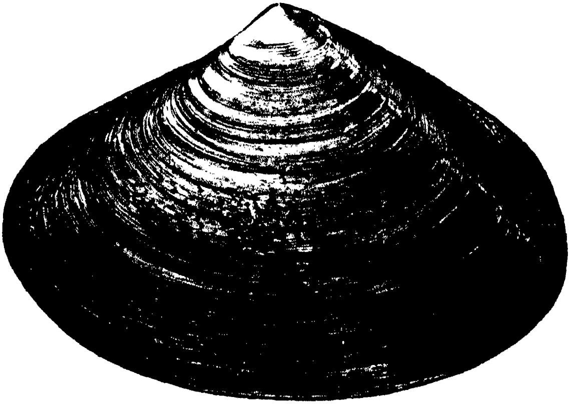


Fig. 173.—*Glycimeris siliqua*, natural size.—After Morse.

A very aberrant form of bivalve mollusk is *Clavagella*, in which the shell is oblong, with flat valves, the left cemented to the sides of a deep burrow. The tube is cylindrical, fringed above and ending below in a disk, with a minute central fissure, and bordered with branching tubules. In *Aspergillum*, the watering-pot shell, the small bivalve shell is cemented to the lower end of a long shelly tube, closed below by a perforated disk like the "rose" of a watering-pot.

The most aberrant Lamellibranch is the ship-worm, *Teredo navalis* Linn. (Fig. 179). This species is now cosmopolitan, and everywhere attacks the hulls of ships and the piles of wharves. It is one of the most destructive to human interests of all animals. The body is from one to two feet long, slender, fleshy; it lives in a burrow lined with limestone, while the shell itself is globular, and lodged at the farther end of the tube or burrow. The mantle lobes of the animal are united, with a minute opening for the foot, which is small, sucker-like. The heart is not pierced by the intestine, while the siphons are very long and furnished with two shelly styles.



174.—*Mactra ovalis*, natural size.—After Morse.

Pearls are sometimes produced in bivalve shells by particles of sand getting in between the mantle and the shell, which cause an irritation to the tissues of the mantle and the formation of a nacreous shelly matter around the nucleus. Excellent pearls are sometimes found in fresh-water mussels,

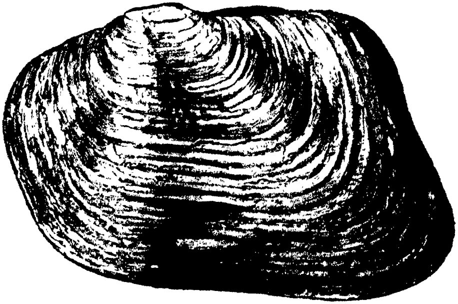


Fig. 175.—*Panopæa arctica*, natural size.—After Morse.

but the purest occur in the pearl oyster, *Meleagrina margaritifera* (Linn.), which occurs at Madagascar, Ceylon, the Persian Gulf, and at Panama. The largest pearl known measures two inches long, four round, and weighs 1800 grains. All bivalves pass through a metamorphosis after birth. The development of the oyster is a type of that of most Lamellibranchs.

Fig. 176.—*Macoma proxima* natural size.—After Morse.

A single oyster may lay about 2,000,000 eggs; they are yellow, and after leaving the ovary are for the most part retained among the gills. In Europe the oyster spawns from June till September; during their growth the eggs are enclosed in a creamy slime, growing darker as the "spat" or young oyster develops.

The course of development is thus: after the segmentation of the yolk (morula stage), the embryo divides into a clear peripheral layer (ectoderm), and an opaque inner layer containing the yolk and representing the inner germinal layer (endoderm). A few filaments or large cilia arise on what is to form the velum of the future head. The shell then begins to appear at what is destined to be the posterior end of the germ, and before the digestive cavity arises. The digestive cavity is next formed (gastrula stage), and the anus appears just behind the mouth, the alimentary canal being bent at right angles. Meanwhile the shell has grown enough to cover half the embryo, which is now in the "Veliger" stage, the "velum" being composed of two ciliated lobes in front of the mouth-opening, and comparable with that of the gastropod larvæ. The young oyster, as figured by Salensky, is directly comparable with the Veliger of the Cardium (Fig. 177). Soon the shell covers the entire larva, only the ciliated velum projecting out of an anterior end from between the shells. In this stage the larval oyster leaves the mother and swims around in the water. According to Brooks the American oyster becomes free-swimming larva in six hours after the egg is fertilized. At a later period it becomes fastened to some rock. The oyster is said to be three years in attaining its full growth, but is able to propagate at the end of the first year.

The development of the cockle (*Cardium pygmæum*), is better known. After passing through a morula and gastrula stage, the embryo becomes ciliated on its upper surface and already rotates in the shell. On one side of the oval embryo is an opening or fissure, on the edges of which arise two tubercles which eventually become the two "sails" of the velum. The next step is the differentiation of the body into head and hind body, *i.e.*, an oral (cephalic) and postoral region. Out of the middle of the head grows a single very large cilium, the so-called flagellum (Fig. 177 *A*, *fl*; *v*, velum). The shell (*B*, *sh*) and mantle (*mt*; *ml*, muscle) now begin to form. From the inner yolk-mass are developed the stomach, the two liver lobes (*li*) on each side of the stomach (*t*), and the intestine (*i*). The mouth (*m*), which is richly ciliated, lies behind the velum, the alimentary canal is bent nearly at right angles, and the anus opens behind and near the mouth. The velum (Fig. 177 *B*, *v*) really constitutes the upper lip, while a tongue-like projection (*B*, *f*) behind the mouth is the under lip, and is destined to form the large unpaired "foot," so characteristic of the mollusks. The shell arises as a cup-shaped organ in both bivalves and univalves, but the hinge and separate valves are indicated very early in the Lamellibranchs. At the stage represented

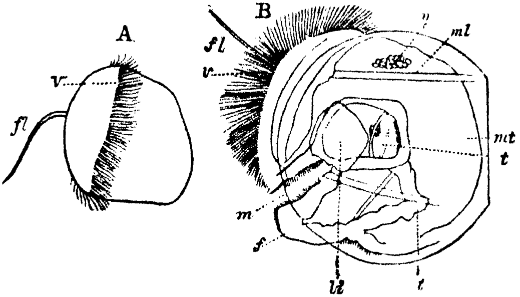


Fig. 177.—The development of the cockle shell (Cardium). *A*, the trochosphere; *v*, ciliated crown; *fl*, flagellum. *B*, Veliger stage, with the shell developing; *v*, velum; *m*, mouth; *li*, liver lobes; *t*, stomach; *i*, intestine; *mt*, mantle; *f*, foot; *ml*, muscle; *n*, nervous ganglion.—After Lovén.

by Fig. 177 *B*, the stomach is divided into an anterior and posterior (pyloric) portion. The liver forms on each side of the stomach an oval fold, and communicates by a large opening with its cavity; while the intestine elongates and makes more of a bend. The organ of hearing then arises, and behind it the provisional eyes, each appearing as a vesicle with dark pigment corpuscles arranged around a refractive body. The nerve-ganglion (*n*) appears above the stomach. The two ciliated gill-lobes now appear, and the number of lobes increases gradually to three or four. The foot grows larger, and the organ of Bojanus, or kidney, becomes visible. The shell now hardens; the mouth advances, the velum is withdrawn from the under side to the anterior end of the shell. In this condition the Veliger remains for a long time, its long flagellum still attached, and used in swimming even after the foot has become a creeping organ. Latest of all appears the heart, with the blood-vessels.

Upon throwing off the Veliger condition, the velum contracts, splits up and Lovén thinks it becomes reduced to the two pairs of palpi, which are situated on each side of the mouth of the mature Lamellibranch. The provisional eyes disappear, and the eyes of the adult arise on the edge of the mantle.

In the fresh-water mussels (*Unio*) the developmental history is more condensed. The velum of the embryo is wanting or exists in a very rudimentary state. The mantle and shell are developed very early. The young live within the parent fastened to each other by their byssus. The shell (Fig. 178) differs remarkably from that of the adult, being broader than long, triangular, the apex or outer edge of the shell hooked, while from different points within project a few large, long spines. So different are these young from the parent that they were supposed to be parasites, and were described under the name of *Glochidium parasiticum*. They are found in the parent mussel during July and August.

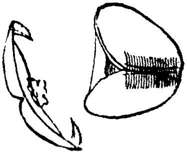


Fig. 178.—Young *Unio*. —After Morse.

The ship-worm (*Teredo navalis* Linn. Fig. 179) after the segmentation of the yolk (Fig. 180 *A*) passes through a veliger stage, the shell begins to grow, and when five days and a half old the germ appears as in Fig. 178, *B*, the shell almost covering the larva. Soon after this the velum becomes larger, and then decreases, the gills arise, the auditory sacs develop, the foot grows, though not reaching to the edge of the shell, and the larva can still swim about free in the water. When of the size of a grain of millet, it becomes spherical, as in Fig. 180, *C*, brown and opaque. The long and slender foot projects far out of the shell, and the velum assumes the form of a swollen ring on which is a double crown of cilia. The ears and eyes develop more, and the animal alternately swims with its velum, or walks by means of the foot. At this stage Quatrefages thinks it seeks the piles of wharves and floating wood, into which it bores and completes its metamorphosis. On the coast of New England the ship-worm lays eggs in May and probably through the summer.

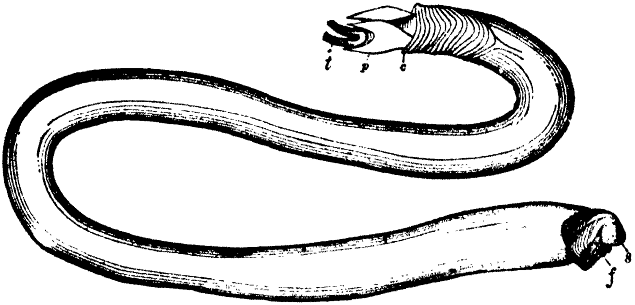


Fig. 179.—The Ship worm. *t*, siphons; *p*, pallets; *c*, collar; *s*, shell; *f*, foot.—After Verrill.

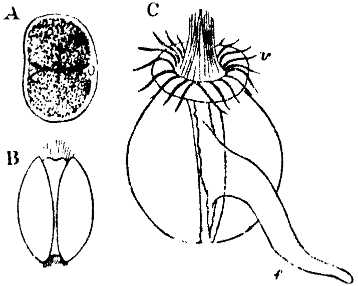


Fig. 180.—Development of the A, egg, with the yolk once divided; B, the veliger enclosed by the bivalve shells; C, advanced veliger with the large foot (*f*) and velum (*v*).—After Quatrefages.

Indeed most mollusks spawn in the summer. Species of *Kellia*, *Galeomma*, and *Montacuta* are viviparous.

Some bivalves get their growth in a single year. The fresh-water muscles live from ten to twelve years and perhaps longer; while *Tridacna gigantea* probably lives from sixty years to a century. Of about 14,000 known species of Lamellibranchs, from 8000 to 9000 are fossil.

CLASS I.—LAMELLIBRANCHIATA.

Bilaterally symmetrical mollusks, with two valves lined by the mantle, connected by a dorsal hinge and ligament; no head; mouth unarmed, with two pairs of labial palpi; intestine coiled in the visceral mass, usually passing through the ventricle, and always ending at the posterior, usually siphon-bearing, end of the body. Foot small, sometimes nearly wanting, never used as a creeping disk. Usually two pairs of large leaf-like gills on each side of the visceral mass. Sexes usually in separate individuals. Embryo passing through a so-called morula, gastrula, and free-swimming veliger condition.

Order 1. *Asiphonia.*—Body-wall or mantle without siphons. Shell sometimes inequivalve. (Ostrea, Anomia, Pecten, Meleagrina, Mytilus, Arca, Trigonia, Unio, and Anodonta.)

Order 2. *Siphoniata.*—Siphons present. Shell equivalve. (Chama Tridacna, Cardium, Venus, Mactra, Tellina, Solen, Clavagella, Aspergillum.)

Laboratory Work.—In dissecting the clam, etc., the work should be performed under water, in a dissecting trough. One shell should be removed by cutting the adductor by a pointed scalpel, the mantle dissected off and thrown aside, so as to expose the gills, heart, and kidneys. In dissecting the nervous system it is well to introduce a probe into the mouth, and then cut down towards it from above, when the white supraœsophageal ganglia or "brain" will be found, and the other ganglia can thence be traced by the commissures leading from the "brain." To find the pedal ganglia and otocyst, cut the foot vertically in two. The heart can be readily found, and the large vein at the base of the gills, but the arterial and venous systems can only well be studied after making careful injections. For ordinary or even quite fine injections, Sabatier used a mixture of lard and turpentine, sometimes adding a little suet or wax to thicken the paste, which was colored chrome yellow, vermilion, or blue. For histological examination he used essence of turpentine, colored as before, or gelatine colored by carminate or ammonia, or Prussian blue dissolved in oxalic acid, or the precipitate of chromate of lead, or he even injected air into the vascular cavities. The mollusk should, before injection, be allowed to slowly die for several days, and the fluids to leave the body. The injection should be made before decomposition has set in, otherwise the vessels will burst. Some anatomists plunge mollusks into water to which has been added alcohol and chlorhydric acid. After remaining in this fluid for a day or two they can be injected. The arterial system can best be injected by the aortic bulb, or aorta: the venous system may be filled from the foot through the aquiferous orifice, by the adductor muscle, or by any of the large veins. After injection the animal should be plunged into cold water to hasten solidification and then placed permanently in alcohol.

CLASS II.—CEPHALOPHORA (*Whelks, Snails, etc.*).

General Characters of Cephalophores.—We now come to *Mollusca* with a head, distinguishable from the rest of the body, bearing eyes and tentacles; but the bilateral symmetry of the body, so well marked in the *Acephala*, etc., is now in part lost, the animal living in a spiral shell; still the foot and head are alike on both sides of the body; while the foot forms a large creeping flat disk by which the snail glides over the surface. Moreover, these mollusks have, besides two pharyngeal teeth, a lingual ribbon or *odontophore.* In a shelless land-snail (*Onchidium*) Semper has discovered the existence of dorsal eyes, constructed, as he claims, on the Vertebrate type. They are in the form of little black dots scattered over the back of the creature, and their nerves arise from the visceral ganglion. Familiar examples of the *Cephalophora* are the sea-snails, the sea-slugs, and the genuine air-breathing snails and slugs.

Order 1. *Scaphopoda.*—A very aberrant type of the class is *Dentalium,* the tooth snail, common in the ocean from ten to forty fathoms deep, on our coast. It lives in a long slender tooth-like shell, open at both ends, while the animal has no head, eyes, or heart, and the foot is trilobed. Owing to the presence of a lingual ribbon, we would retain it in the present class, though it is a connecting link between this and the preceding class, and is, by some authors, regarded as the type of a separate class (*Scaphopoda*). The sexes of *Dentalium* are distinct. The young is a trochosphere and afterwards becomes segmented, and the univalve shell then appears. (Fig. 182.)

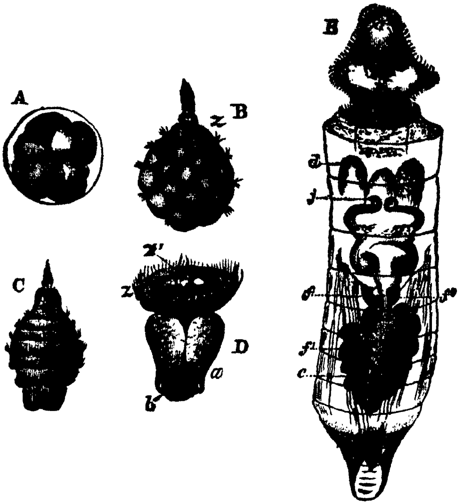


Fig. 181.—Development of *Dentalium*. *A*, morula; *B*, trochosphere; *C*, annulated larva; *D*, larva with its rudimentary shell; z, velum; *a*, shell; *E*, young much farther advanced, the shell or body segmented; *d*, rudimentary tentacles; *j*, subœsophageal nerve-ganglia; ff'', digestive canal, and liver (f'); the foot protrudes from the shell. All magnified.—After Lacaze-Duthiers.

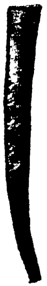


Fig. 182.—*Dentalium Indianorum.* Used as shell money.—After Stearns.

Order 2. Pteropoda.—In these winged-snails the head is slightly indicated and the eyes are rudimentary; while they are easily recognized by the large wing-like appendages (*epipodium*), one on each side of the head. The shell is conical or helix-like. The species are hermaphroditic. *Cavolina tridentata* Lamarck and *Styliola vitrea* Verrill (Fig. 183) are pelagic forms, occurring on the high seas, and are occasionally taken with the tow-net off the southern coast of New England. *Limacina arctica* Fabr. is of the size of, and looks like, a sweet pea, moving up and down in the water. It is common from Labrador to the polar regions.

A common form, occurring at the surface in harbors north of Cape Cod, as well as many miles off shore, is *Spirialis Gouldii* Stimpson, the shell of which resembles a conical Helix. The largest form on the eastern coast of North America, extending from New York to the polar seas, is the beautiful *Clione papillonacea* of Pallas, which has a head and lingual ribbon. It is rare on the coast of New England, but abundant from Labrador northward. We have observed it rising and falling in the water between the floe-ice on the coast of Labrador. It is an inch long, the body fleshy, with no shell, the wings being rather small.

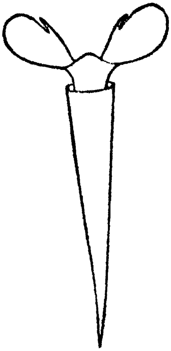


Fig. 183. — *Styliola vitrea.*—After Verrill.

The larvæ of the Pteropods pass through a trochosphere stage, being, as in *Cavolina*, spherical, with a ciliated crown. It afterwards assumes a veliger form. Fig. 184 represents a worm-like, segmented, Pteropod larva, the adult of which is unknown. In other genera the larvæ are annulated, resembling the larvæ of Annelides.

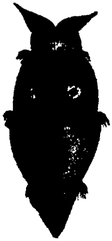


Fig. 184.—Pteropod larva.

The Pteropods are, in some degree, a generalized type. They have a wide geographical distribution and a high antiquity; forms like *Cavolina*, viz.: *Theca*, *Conularia*, *Tentaculites*, *Cornulites*, etc., dating back to the palæozoic formation; Theca-like forms (*Pugiunculus* and *Hyolithes*) occurring in the primordial rocks.

Order 3. *Gastropoda.*—This great assemblage of mollusks is represented by the sea-slugs, limpets, whelks (Figs. 185–188), snails, and slugs. The head is quite distinct, bearing one, and sometimes, as in the land-snails, two pairs of tentacles, with eyes either at the bases, or at the ends of the tentacles, or, as in *Trivia californica* (Fig. 189), they are situated on projections near the base of the tentacles. All the Gastropods move or glide over the surface by the broad creeping-disk, a modification of the foot of the clam, etc. The head is alike on each side, but posteriorly the body

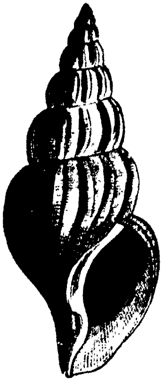


Fig. 185.

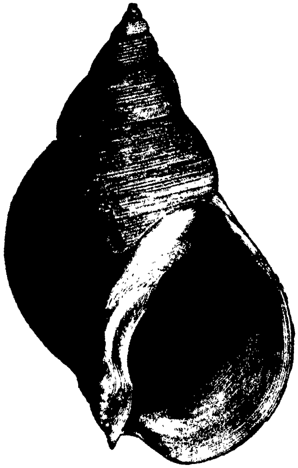


Fig. 186.

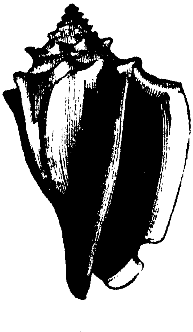


Fig. 187.

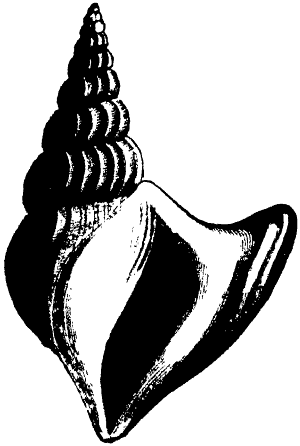


Fig. 188.

Fig. 185.—A Whelk. *Buccinum cretaceum.* Labrador.
Fig. 186.—A Whelk. *Buccinum ciliatum.*—After Morse.
Fig. 187.—*Strombus pugilis.* West Indies.—From Tenney's Zoology.
Fig. 188.—Pelican's Foot. *Aporrhais occidentalis.* Northern New England.-After Morse.

is, in those species inhabiting a spiral shell, asymmetrical and wound in a spiral, the visceral mass extending into the apex of the shell. In the Nudibranchs (Figs. 195, 197), and the slug, the body being naked is symmetrical on each side.

The digestive tract is doubled on itself, the vent ending on one side of the mouth. In some Nudibranchs the intestine has numerous lateral offshoots, or gastro-hepatic branches, which resemble similar structures in the Planarian and Trematode worms. A heart is always present, except in the parasitic *Entoconcha*, and sometimes, as in *Chiton*, *Neritina*, and *Haliotis*, it is perforated by the intestine. In some genera there are two auricles to the heart, but as a rule but one is present. The Gastropods breathe by gills either free, or contained in a cavity in the mantle, while in the land-snails (*Pulmonata*) the air is breathed directly by a lung-like gill in a mantle-cavity. The kidney is single. The sexes are either distinct or united in the same individual.

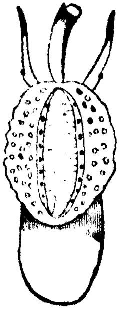


Fig. 189. — *Trivia californica* enlarged twice.—After Stearns.

An excellent idea of the structure of a typical Gastropod may be obtained by a dissection of *Natica* (*Lunatia*) *heros*. This is a large mollusk, common between tide-marks from Labrador to Georgia. On taking it up the student will notice the large, round, swollen, porous foot, from which the water pours as if from the "rose" of a watering-pot. The shell is large, composed of several whorls, with a small flattened spire or apex. The aperture is large, lunate in shape, and can be closed by a large horny door or *operculum*. (In some mollusks, *Natica*, *Turbo*, etc., the operculum is of solid limestone, and small ones are used as "eye-stones," being inserted in the eye and moved about by the action of the lids, thus cleansing the eye of irritant particles of dust, etc.)

The animal should then be placed in a dish of salt water, and its movements observed. There are but two short, broad, flattened tentacles, situated on a flap or head-lobe (*prosoma*) of the mantle or body-walls. No eyes are present in this species. The mouth is situated in front of the foot and at the base of the head-lobe, and is bounded by large puckered swollen lips. Cutting down from between the tentacles, a large buccal mass, the pharynx, is exposed. The mouth-cavity is roofed with two broad quadrant-shaped, flat thin teeth, with the free-edge serrated. On the floor of the mouth lies the "tongue," or lingual ribbon (Odontophore), which is folded once on itself, and is a thin band composed of seven rows of teeth, those forming the two outer rows long and much curved, those of the central row being stout and three-toothed. The long slender œsophagus is tied down, near its middle, by the brain (supraœsophageal ganglion); just behind and beneath which are the two large salivary glands. The œsophagus suddenly dilates into a *large stomach-like pouch, which is much larger in this species than in other forms allied to it. It is a sort of crop* or proventriculus (the organ of Delle Chiaje), and rarely occurs in the Gastropods. On laying it open, it may be seen to be spongy at its anterior end, and posteriorly divided by numerous transverse partitions into small cavities. The œsophagus beyond it is again slender, and leads to the stomach situated in the apex of the shell, partly embedded in the liver-mass which lies mainly beyond it. From the stomach the intestine returns to the head, widely dilating into a large sacculated cloaca, before the free upturned vent, which is situated on the right side behind and to the right of the right tentacle. The nervous system is represented by a pair of large ganglia, forming the brain (supraœsophageal ganglia) situated just below and behind the pharynx. The two other ganglia were not traced, but as a rule in all *Cephalophora* there are three pairs of ganglia, *i. e.*, the brain (supraœsophageal ganglia) with commissures passing around the gullet to the pedal or infraœsophageal ganglia, thus forming the œsophageal nervous ring, while the visceral or parieto-splanchnic ganglia are placed at a varying distance behind the head.

The heart, contained in its pericardial sac, and consisting of a ventricle and auricle, is situated near the posterior end of the gills. The latter are disclosed by laying aside the mantle on the left side of the body behind the head. In a large *Lunatia* it is an inch long, with a vein at the base, the gill-lobes arranged like the teeth in a comb. A smaller, much narrower gill lies within and parallel to it. The ovary is situated near the stomach, the oviduct ending near the vent.

The eggs are laid in capsules (Fig. 190, *Purpura lapillus* and two egg-capsules) of varied form attached to rocks or, as in *Trochus* and the Nudibranchs, in masses of jelly attached to sea-weeds or stones.

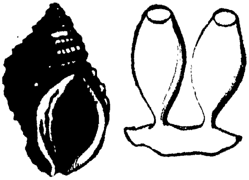


Fig. 190.—*Purpura* and its egg capsules, the latter enlarged.—After Morse.

As a type of the mode of development of Gastropods may be cited that of *Calyptræa sinensis*, represented in our waters by *Calyptræa striata* Say (Fig. 191).

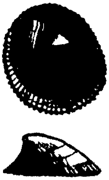


FIG. 191.

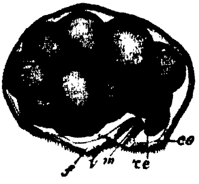


FIG. 192.

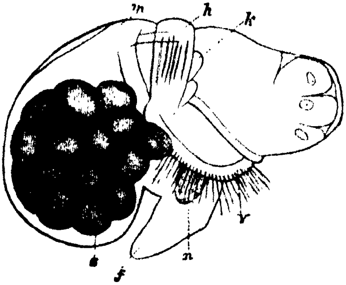


FIG. 193.

Fig. 191.—*Calyptræa striata*, natural size.—After Morse.

Fig. 192.—Veliger of *Calyptræa*. *f*, foot; *v*, velum; *m*, mouth; *ce*, ectoderm; *'ce*, mesoderm.—After Salensky.

Fig. 193.—Veliger of *Calyptræa* further advanced. *m*, mantle; *v*, velum; *f*, foot; *h*, larval heart; *n*, permanent; *k*, primitive kidney; *s*, crosses the shell and rests on the yolk.—After Salensky.

According to Salensky, after segmentation of the yolk into eight cells the first four cells or "spheres of segmentation" subdivide, enclosing the yolk-mass, and constituting the ectoderm or outer germ-layer, the yolk-mass forming the endoderm. The cells of the outer germ-layer multiply and form the blastoderm, from which the skin, mantle, and external organs, as well as the walls of the mouth, arise. The "primitive" mouth of the gastrula is formed by the invagination of the outer germ-layer; the sides of the primitive mouth form the two sails of the velum or swimming organ, and the embryo now assumes the veliger stage (Fig. 192). Soon the middle germ-layer (mesoderm) arises, and from the cells composing it are developed the muscles of the foot and head, as well as the heart itself. The mantle or body-wall next develops, and from it the shell, which originates in a cup-like cavity which is connected only around the edge with the mantle, being free in the centre. The eyes and ears, or otocysts, next appear, both organs arising as an infolding of the outer germ-layer. Hitherto symmetrical, the alimentary canal now begins to curve to the left, and the visceral sac, or posterior part of the embryo hangs over on one side. The nervous system is the last to be developed.

Fig. 193 represents the asymmetrical larva with the shell enveloping a large part of the body, and the ciliated velum (*v*) and foot (*f*) well developed. A temporary larval heart (*h*) assumes quite a different position from the heart of the adult, and the primitive, deciduous kidney (*k*) is situated in quite a different place from the permanent kidney. The further changes consist in a gradual development of the helmet-like shell, the disappearance of the temporary larval structures, and the perfection of the organs of adult life, the gills appearing quite late.

The development of *Trochus*, the top-shell, exhibits more strikingly the trochosphere and veliger stages of molluscan life, and most Gastropods develop like this form. The velum at first forms a ciliated ring (Fig. 194, *A*, v) on the front end of the trochosphere. Fig. 194, *B*, represents the veliger state.

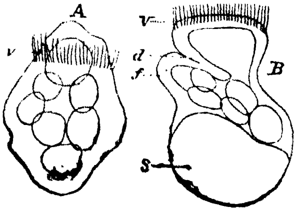


Fig. 194.—Larval *Trochus*. *A*, trochosphere; *v*, velum; *B*, veliger state; *d*, mouth; *f*, foot; *s*, shell.—After

It thus appears that the temporary larval or veliger form of the Gastropods are of vermian origin, the organs last to be developed, *i. e.*, the foot, shell and lingual ribbon, which are the distinctively molluscan characters, being the last to appear.

The Nudibranch mollusks, such as the *Eolis* and *Doris* and allied forms, breathe by external gills, arranged in bunches on the back, as seen in Fig. 195, *Æolis* (Montagua) *pilata* (Gould), a common species on the coast of New England. In Doris (Fig. 197), they are confined to a circle of pinnate gills on the hinder part of the back. They are shelless, and not uncommon just below low-water mark, laying their eggs in jelly-like masses coiled up on stones and the surface of sea-weeds. Though the adults are shelless, the embryos at first have a shell (Fig. 196, *s*), indicating that the Nudibranchs have descended from shelled Gastropods. Fig. 196 represents the veliger of *Tergipes lacinulata* Schultze, allied to *Doris*, with its large ciliated velum, and protected by a deciduous shell, which finally disappears with the velum.

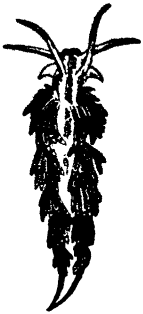


FIG. 195.

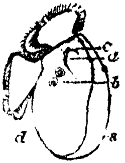


FIG. 196.

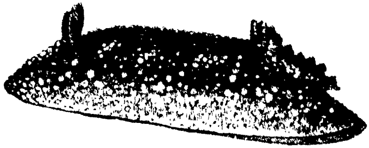


FIG. 197.

Fig. 195.—*Æolis*, a Nudibranch.
Fig. 196.—Veliger of *Tergipes*. *v*, velum; *s*, shell; *d*, foot; *b*, otocysts.—After Schultze.
Fig. 197.—*Doris bilamellata*. New England coast.

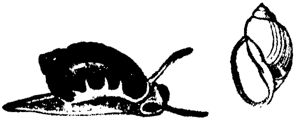


Fig. 198.—*Physa heterostropha*. Common pond-snail.—After Morse.

The air-breathing mollusks, *Pulmonata*, are represented by the pond-snails, *Physa* (Fig. 198) and *Limnæus* (Figs. 199, 200), and the land-snails and slugs. Fig. 205 represents a slug suspended by a mucous thread from a twig.

The common snail, *Helix albolabris* Say, is a type of the air-breathing mollusks. Fig. 201 represents this snail of natural size, in its shell. The opening to the lung is seen at *a*, and at B is represented the heart and lung of the garden slug (*Limax flavus*). Fig. 202 represents *Helix albolabris* with the shell removed, and the mantle thrown back.

showing the lung and heart (*h*) and the mouth (*m*) as well as the four tentacles, with an eye at the end of the two upper tentacles. Fig. 203 shows the brain and pedal ganglia of *Helix albolabris*. The tentacles when carefully examined may be found to contain both the eyes (*e*) with the optic nerve (*op*) and the olfactory nerve (Fig. 206, *o*). Fig. 204 represents the jaw and lingual ribbon of Helix.

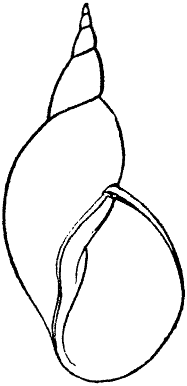


Fig. 199.—*Limnæus appressus.*—After Morse.

The eggs of the pond-snails are laid in transparent capsules attached to submerged leaves, etc. Those of *Physa heterostropha* are laid in the early spring, and three or four weeks later from fifty to sixty embryos with well-formed shells may be found in the capsule.

The eggs of *Limnæus* are laid late in the spring in capsules containing one or two eggs, and surrounded by a mass of jelly. After passing through the morula, gastrula, and trochosphere stages a definite veliger stage is finally attained. The foot is large and bilobed, the mantle and shell then arise, and the definite molluscan characters are assumed, the shell, creeping foot, mantle-flap, eyes, and tentacles appearing, and the snail hatching in about twenty days after development begins.

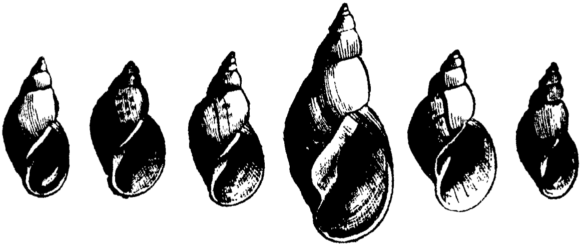


Fig. 200.—*Limnæus elodes*, a common pond-snail, showing its variations.—After Morse.

Land-snails and slugs lay their eggs loose under damp leaves and stones, and development is direct, the young snail hatching in the form of the adult.

FIG. 201.

FIG. 202.

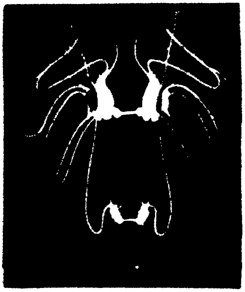


FIG. 203.

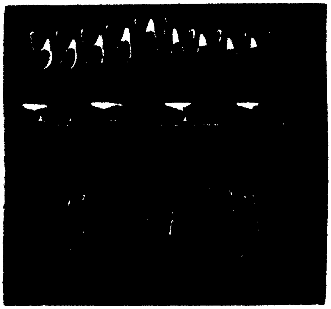


FIG. 204.

Fig. 201.—*Helix albolabris*, natural size. *a*, orifice of lung. Also the heart and lung of *Limax flavus*, magnified.

Fig. 202.—*Helix albolabris*, with the shell removed to show the heart (*h*) and the lung; *m*, mouth.—This and Figs. 201-204 after Leidy.

Fig. 203.—Nerve-centres of *Helix albolabris*.

Fig. 204.—Jaw (lower figure) and side and top view of teeth of lingual ribbon of *Helix albolabris*.

The group of mollusks represented by *Chiton* (Fig. 207, *Chiton ruber*) have been referred to the worms by Jhering, on account of the segmented appearance of the plated shell, and the nervous system, which consists of two parallel cords, connected by several commissures;* as well as from the fact that the intestine ends at the hinder end of the body. The young is oval when hatched, and is a trocho- having ciliated ring in the middle of the body with a long tuft of large cilia on the head. Afterwards it becomes segmented, as in Fig. 208, and is remarkably worm-like, the *limestone plates of the adult corresponding to the primitive larval rings.*

Fig. 205.—Slug. Natural size.

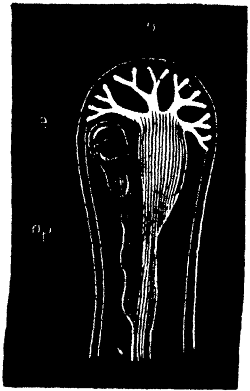


Fig. 206.—End of tentacle of a snail. *e*, eye; *op*, optic nerve; *o*, olfactory nerves.

Certain Gastropods are useful either as food or in the arts. In Europe *Littorina littorea*, the limpet (*Patella vulgata*), the whelk (*Buccinum undatum*), and the Roman snail (*Helix pomatia*) are eaten. The sea-ear (*Haliotis*) is roasted in the shell. The animal of *Cymba*, *Strombus gigas*, *Turbo*, *Trochus*, and *Conus* are eaten in the tropics, while many of the larger forms are used for fish-bait. Pearls are sometimes found in the species of *Haliotis* and *Turbo.* The beautiful shell of *Cassis* is made into cameo pins, and the shell of *Strombus gigas* is in the West Indies made into ornaments.

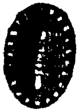


FIG. 207.

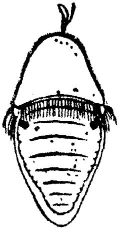


FIG. 208.

Fig. 207—*Chiton ruber*.
Fig. 208.—Segmented larv of *Chiton*.

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* In *Fissurella* and *Haliotis* the two nerve-cords from the pedal ganglia are also united by nine transverse commissures, so that here also we have an approach to the double ganglionated cord of worms.

Various shells, such as *Marginella*, *Turbinella*, etc., are strung in bracelets and armlets by savages. *Cypræa moneta*, the cowry (Fig. 209), is used for money, and other shells are worked into various shapes for wampum or aboriginal money. Fig. 210 represents an *Olivella*, used by the Californian Indians as money. *Murex* and *Purpura* afford the Tyrian dye.

While a few Gastropods are pelagic, living upon the high seas, such as *Ianthina* and the Nudibranch *Glaucus*, most of the species are submarine and live in all seas; the hardier, most widely diffused species living between tide-marks, the more delicate forms in deep water, ranging from low-water mark to fifty or one hundred fathoms. The abyssal fauna at the depth of from 500 to about 2000 fathoms has a few characteristic mollusks. Many live on land and in fresh water.

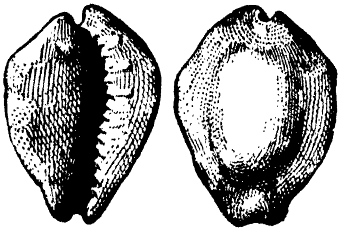


FIG. 209.

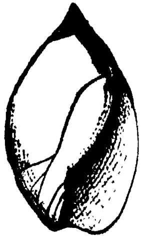


FIG. 210.

FIG. 209.—*Cypræa moneta*.—After Stearns.
FIG. 210.—*Olivella biplicata*.—After Stearns.

The largest, most highly colored shells live in the tropics, while those found in the temperate zones are less beautiful, and the arctic species are the smallest and dullest in color. The shells of the eastern coast of North America are divided into several assemblages, or faunæ, the West Indian or tropical shells, in some cases, reaching as far north as Cape Hatteras; between this point and Cape Cod a north temperate assemblage occurs, and north of Cape Cod the molluscan fauna is essentially Arctic; many species being common to the arctic and subarctic seas of the circumpolar regions.

Marine shells in time date back to the lowest Silurian period; such are *Maclurea, Holopea, Murchisonia, Pleurotomaria,* etc., which occur fossil in rocks of the Potsdam period. The Palæozoic Gastropods are few in number compared with those occurring in Cretaceous and especially Tertiary formations.

The earliest land-snails occurred in the Coal Period; the living species are exceedingly numerous, and often much restricted in range, especially in the tropics; the arctic forms are very scarce, but four or five species occurring in Greenland. There are over 22,000 species of *Cephalophora* known, of which 7000 are fossil. There are 6500 species of *Pulmonata.*

Subclass 4. *Heteropoda.*—The Heteropods form a distinct subclass, the systematic position of which was for a long time unsettled; but they are now classed among the Gastropods, being in fact related to the *Opisthobranchiata.* Their most striking peculiarity is the form of their foot, the anterior and middle portions of which are expanded to form a leaf-like fin, which often bears a sucker; the posterior part of the foot is much elongated, and, reaching far backwards, appears to form a tail-like continuation of the body. The Heteropods are more or less transparent, and are found swimming upon the surface of the ocean, upon their backs with their foot upwards. The shell may or may not be developed; when present it may be either simple or coiled. The nervous system resembles closely that of the true Gastropods, but is more highly developed; the brain consists of several supraœsophageal ganglia forming part of an œsophageal ring. From the brain arise the optic and auditory nerves. The two large eyes lie in special capsules near the feelers, and are movable by several muscles. The otocysts are also large, and contain a large spherical otolith. The otocysts are lined by an epithelium with bundles of long vibratile hairs, and with a cluster of sensory cells, forming a *macula acustica.* Organs of touch have also been described. The sensory apparatus of the Heteropods are highly specialized, and have been studied by Claus, Boll, Flemming, and others. The odontophore is well developed;

the tongue or *radula* has highly characteristic teeth, which serve these rapacious animals to seize their prey. The intestine runs straight back from the mouth, and after making one or two coils ends in the vent. The excretory organs open near the anus; the contractile tube opens internally into the pericardial cavity, and resembles in form and position the excretory organ of the *Pteropoda*. The circulation is imperfect, the blood passing from the wide sinuses of the body to the ventricle of the heart. From the auricle springs the aorta, which subdivides into several branches that open freely into the body-cavity. The circulation can be easily watched, owing to the transparency of the body. The aëration of the blood is effected partly through the skin, partly through gills, except in a few species. The branchiæ are either thread- or leaf-like ciliated appendages, which may either be free or enclosed in the mantle-cavity. The sexes are distinct. The males can be readily recognized by the large copulatory organ, which hangs free on the right side of the body. The sexual glands fill the posterior portion of the visceral cavity, and are partly imbedded in the liver. The oviduct is complicated by the presence of an albumen gland and a *receptaculum seminis*. It opens on the right side of the body.

The Heteropods are exclusively marine, but are found in all quarters of the world. The number of species is small, and there are two orders only—the *Pterotracheidæ* with a small or no shell and free gills, and the *Atlantidæ* with a large coiled shell and gills placed in the mantle. *Pterotrachea* (*Firola*) *coronata* Forsk. is found in the Mediterranean, and on account of its transparency has often been investigated. The *Heteropoda* live together in large numbers, and feed on small animals.

The eggs are laid in cylindrical strings, which soon break up into numerous pieces. The segmentation of the yolk is complete but irregular. The embryo rotates within the egg during the *veliger* stage, when it has two distinct sails, or lobes of the velum, and a ciliated foot with an operculum. In this form it leaves the egg. The velum enlarges and forms several divisions. The otocysts, eyes, and tentacles are then developed. The foot gradually lengthens and forms the characteristic fin or keel. The velum is meanwhile absorbed, the operculum (*Carinaria*), or the operculum and shell, are thrown off, and the larva gradually assumes the form and organization of the adult. The close relationship of the Heteropods and Gastropods is shown by the great similarity of their larvæ. Gegenbaur even goes so far as to include them under the *Opisthobranchiata*, while von Jhering unites them with Chitons and some other forms under the name of *Arthrocochlidæ*; for the present it seems best to retain them as a subclass.

The fossil genus *Bellerophon* is closely related to the *Atlantidæ*.

CLASS II.—CEPHALOPHORA.

Mollusks with a distinct head, with tentacles, eyes and ears in the head; the foot forming a creeping disk; the body either naked and bilaterally symmetrical, or enclosed in a spiral shell, and consequently behind the head asymmetrical. Mouth with pharyngeal teeth and a lingual ribbon (odontophore). Nervous system consisting of four pairs of ganglia, the brain well developed. The intestine usually ending near the mouth. The heart with usually a single auricle. Breathing by a single gill, or a lung-like gill; a double kidney, but forming a single mass. Sexes united or separate. Young passing through a morula, gastrula, sometimes a trochosphere and usually a veliger stage; in the land-snails development direct.

Subclass 1. *Scaphopoda.*—No head, several long thread-like tentacles; foot long, trilobed. Shell long, conical, open at each end. A single order *Solenoconchæ*. (Dentalium, Siphonodentalium.)

Subclass 2. *Pteropoda*—Body with two wing-like expansions (velum) on the front part of the foot, for swimming; body naked or shelled. Hermaphroditic. Larva with a velum and shell. Order 1. *Thecostomata* (Hyalea, Cleodora, Cavolina). Order 2. *Gymnosomata*. (Clione).

Subclass 3. *Gastropoda.*—Order 1. ***Prosobranchiata*** (Haliotis, Patella, Trochus, Littorina, Lunatia, Paludina, Turritella, Ianthina, Cypræa, Strombus, Cassis, Buccinum, Nassa, Purpura.) Order 2. *Opisthobranchiata*. (Bulla, Aplysia, Eolis, Doris.) Order 3. *Pulmonata*. (Limnæus, Planorbis, Auricula, Helix, Bulimus, Limax).

Subclass 4. *Heteropoda.*—Naked or shell-bearing mollusks, with a large prominent head, large movable eyes, and foot with a keel-like fin. The sexes are distinct. Respiration by gills. Order 1. *Pterotracheidæ.*—Pterotrachea, Carinaria, Firoloides. Order 2. *Atlantidæ.*—Atlanta (living); Bellerophon (fossil).

Laboratory Work.—The Gastropods are very difficult to dissect, and it is quite essential that the specimen be freshly killed, and that it has died as fully expanded as possible. For this purpose they should be allowed, as Verrill suggests, to die in stale sea-water, with the parts expanded; when the animal is nearly dead, the soft parts can be forcibly held out by the hand while the animal is killed by immersion in alcohol. Shells and other marine animals may be obtained by means of the dredge (Fig. 211), an iron frame with a net, to which is attached a rope and weight.

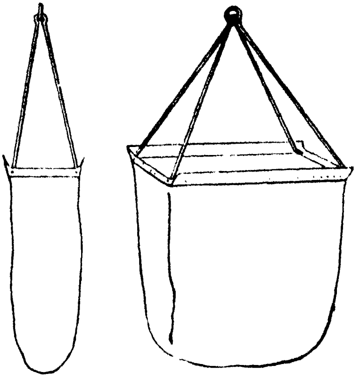


Fig. 211.—Dredge.

CLASS III.—CEPHALOPODA (*Squids and Cuttle-fishes*).

General Characters of Cephalopods.—The essential features of this class may be observed by a study of the common squid, represented by Fig. 212. The following account is based on dissections of *Loligo Pealii* Lesueur (Fig. 213). A general view of the body of the entire squid, with its arms and suckers, is given in the accompanying illustration (Fig. 212) of *Loligo pallida* Verrill. The body is fish-like, pointed behind, and with two broad fleshy fin-like expansions at the end of the body. The head is distinct from the mantle or body, and the mouth is surrounded by a crown of ten long stout pointed arms, provided on the inner side with two rows of alternately arranged cup-shaped suckers, each sucker being spherical, hollow, with a horny rim inside. Two of the ten arms arise from the under side of the head; they are twice the length of the eight others, and oval at the end. On each side of the head behind the tentacles are the remarkably large eyes, which, though usually said to be more like the vertebrate eye than those of any other invertebrate, are really constructed fundamentally on the same plan as the eye of the snail; differing in several important respects from that of a Vertebrate, the resemblances between the two being superficial, while the structure of the eyes of mollusks is quite unlike that of Crustaceans, insects or Vertebrates.

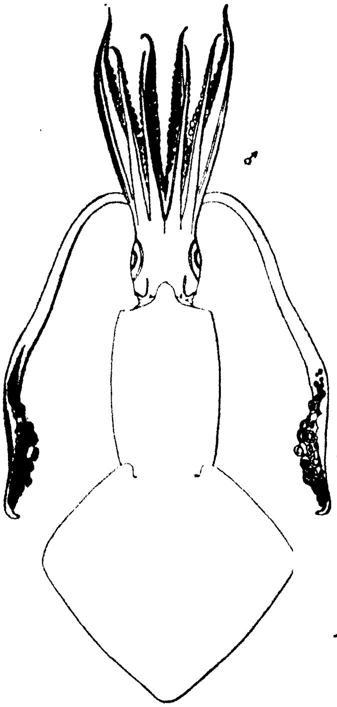


Fig. 212.—*Loligo pallida*; male. A one third natural size.—After Verrill.

The mantle loosely invests the front of the body next to the head, so that the water passes in around the neck in order to bathe the gills, which are quite free from the visceral mass. The mantle is beautifully colored and spotted, the change of color being due to the change in form of the pigment masses or *chromatophores*, which are under the influence of the peripheral nerves.

The mantle is supported by a horny "pen" (Fig. 214), or pen-shaped thin support, extending from the upper side of the anterior edge of the mantle to the end of the body. In the *Sepia* of the Mediterranean Sea this is thick, formed of limestone, and is called the "cuttle-fish bone."

The organs of digestion consist of a mouth, pharynx, œsophagus, stomach and intestine. The mouth is situated

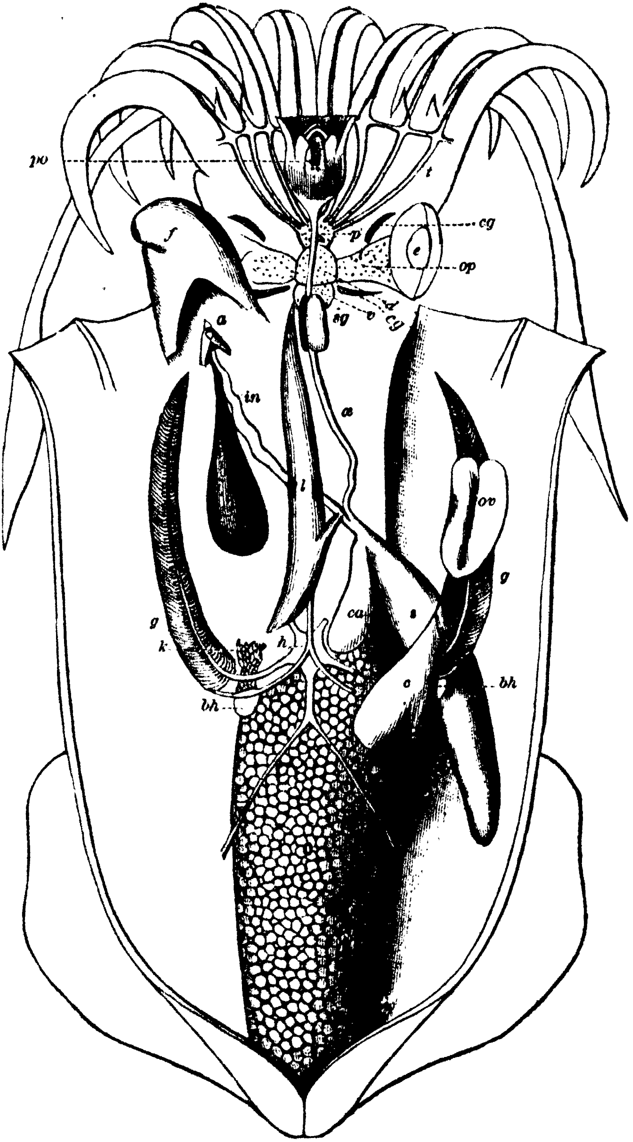


Fig. 213—Anatomy of common squid.—Drawn by J. S. Kingsley, from the author's dissections. The brain (*d*) in nature is situated above the œsophagus.

between the tentacles, and is surrounded by a double fleshy lip, the outer fold of the lip bearing short fleshy pointed lobes opposite the spaces between the tentacles. The pharynx is large, muscular and bulbous, containing two powerful horny teeth, shaped like a parrot's beak; the two jaws are unequal, the lower one the smaller, moving vertically. On opening the base of the smaller jaw, the lingual ribbon or odontophore (Fig. 213, *po*) may be discovered; it consists of seven rows of teeth, somewhat as in those of *Architeuthis Hartingii* (Fig. 215).

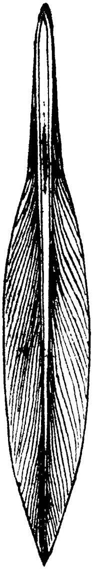


Fig. 214.—Pen of *Loligo pallida*, dorsal side; natural size.—After Verrill.

The œsophagus (*œ*) is long and slender, with two long oval salivary glands (*sg*) on each side of it, just behind the pharynx; the salivary duct leading into the mouth-cavity. The œsophagus has several internal longitudinal folds, and passes on one side of the large liver (*l*) which lies in front of the stomach, and which is about one third as long as the whole body, extending backwards.

On laying open the stomach, a series of large semicircular transverse curved valves may be seen, occupying the anterior third of the stomach (*s*), while beyond are scattered glandular masses. The pyloric end opens into an oval cœcum (*ca*) with about fourteen longitudinal, thin high ridges. There is no spiral portion attached. The intestine (*in*) is straight, thick, and passes forward, ending in a large vent (*a*), the edges of which are lobulated. The "ink-bag" (Fig. 213, *i*) can be recognized as a purse-like silvery sac, filled with a dense pigment, the sepia, which, like the Chinese sepia, can be used for drawing. The duct is straight, and is intimately attached to the intestine, ending close to the vent, both the vent and opening of the duct of the ink-bag being situated at the bottom of the funnel or siphon (Fig. 213, *f*), which is a large

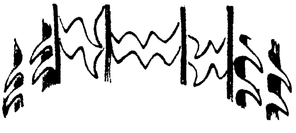


Fig. 215.—Part of lingual ribbon of *Architeuthis Hartingii*; enlarged.

short muscular canal with a large orifice extending on the ventral side to the base of the tentacles. Through this siphon passes excrementitious matter as well as the ink, and the stream of water which is forcibly ejected from the siphon, thus propelling the squid through and sometimes out of the water.

The two gills (Fig. 213, *g*), are large, long slender bodies, attached by a thin membrane to the inner wall of the mantle, and are quite free from the visceral mass. From the branchial vein arise two rows of lamellæ like the teeth of a comb. At the base of each gill is a flatted oval body, the "branchial heart," or auricle (Fig. 213, *bh*). The auricles are quite separate from the large four-cornered flat ventricle (Fig. 213, *h*), lying in front of the stomach, and which throws off an artery from each corner, the aorta being the largest, and passing parallel to the œsophagus, while a large vein (*vena cava*) is sent off to the gills from a circular sinus in the head.

The nervous system is more complicated than usual in *Mollusca*, and is very difficult to dissect. In *Loligo Pealii* the highly concentrated nervous system is mainly contained in an imperfect cartilaginous brain-box (*cg*), a slight anticipation of the skull of the Vertebrates. The brain (supraœsophageal ganglion, Fig. 213, *d*) rests upon the very large optic nerves, which dilate at the base of the eye, the latter being partially imbedded in sockets in the brain-box. The visceral (parietosplanchnic) ganglion lies beneath and a little behind the brain, supplying the nerves for the ears (otocysts), which are enclosed in the cartilaginous brain-box, and there is a fine canal leading from the ears to the surface of the body, so that, as Gegenbaur states, it is possible to distinguish a membranous and a cartilaginous labyrinth, analogous to the similar parts found in the Vertebrates. The pedal ganglion (Fig. 213, *p*) is paired with the visceral ganglion (Fig. 213, *v*), but lies in front of it, behind and under the bulbous pharynx, and from it arise ten nerves (*t*), which are distributed one to each arm, passing between the two rows of suckers. Two smaller ganglia, the superior buccal and inferior buccal, lie one above and one below the beginning of the œsophagus.

Besides this set of five cephalic ganglia, there are three pairs of ganglia belonging to the visceral or sympathetic nerve, which arise from the visceral ganglion situated among the viscera; a single one (the ventricular or splanchnic ganglion) is situated over the stomach near the origin of the aorta, which sends a nerve to the cœcum, and another accompanies the aorta; the mate to this ganglion is situated near the *vena cava.* A pair of ganglia is situated on the mantle walls (*ganglia stellata*), and there are two branchial ganglia. The kidneys (*k*) are irregular branching spongy bodies, in intimate connection with the auricles or branchial hearts. The sexes are distinct. The ovary (*o*) is large, especially when the eggs are ripe, and is situated in the end of the body-cavity. The single oviduct is as in some worms, separate from the ovary, and in this respect the Cephalopods approach or anticipate the Vertebrates, in which the oviduct is also separate from the ovary. The oviduct (*ov*) is a thick straight tube, with a flaring, deeply-lobed mouth. The eggs, when extruded, are enveloped in a large gelatinous capsule (Fig. 216), which is secreted by the large flattened nidamental gland (*c*) on the floor of the body-cavity, tied down at each end by cord-like membranes. Usually there are two nidamental glands.

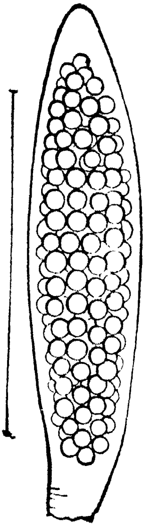


Fig. 216.—Egg-capsule of *Loligo Pealii.* —After Verrill.

The earliest phase of development of the egg of most Cephalopods (*Sepia, Loligo*) is like that of birds and reptiles, the yolk undergoing partial segmentation, the blastoderm being restricted to a small disk, as in Vertebrates. Eventually the blastoderm encloses the whole yolk, the mantle begins to form, the eyes are at first in-pushings of the outer germ-layer, and the mouth appears. The digestive tract originates from a primitive invagination of the outer germ-layer (ectoderm), as in *Amphioxus*, Ascidians, worms, and some Cœlenterates. About the tenth day, as observed by Ussow, at Naples, the gills, siphon or funnel, and arms arise, and a day later the rudiments of the ears, of the pharynx and salivary glands; while a day or two after, the ventricle, auricles, the kidneys, the ink-sac, and liver develop. Contrary to the usual rule the ganglia arise from the middle instead of the outer germ-layer. After this the germ gradually develops until it rises above the surface of the egg, and soon the yolk is partly absorbed and is contained in a large yolk sac, as in Figs. 217, 218. Finally the young cuttle-fish hatches in the form indicated by Fig. 219, and then swims free upon the surface of the sea.

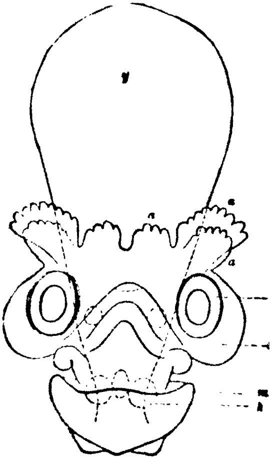


FIG. 217.

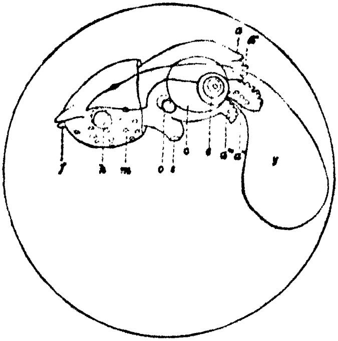


FIG. 218.

Fig. 217.—Embryo of *Loligo Pealii*. *a*, *a''*, *a'''*, *a''''*, the right arms belonging to four pairs; *c*, the side of the head; *e*, the eye; *f*, the caudal fins; *h*, the heart; *m*, the mantle in which the color-vesicles are already developed and capable of changing their colors; *o*, the internal cavity of the ears; *s*, siphon.—After Verrill.

Fig. 218.—The same as Fig. 217, but more advanced. The lettering in Figs. 217 and 218 the same.—Both after Verrill.

The development of Cephalopods in general is, then, direct, *i.e.*, there is no metamorphosis, the phases of metamorphosis seen in most other mollusks not appearing; but in an unknown species of cuttle-fish whose eggs were found floating on the Atlantic, the germ, after the partial segmentation of the yolk, assumed a trochosphere condition (Fig. 220) before the definitive features (Fig. 221) of the cuttle-fish appeared. The squids or cuttle-fish are very active, sometimes leaping out of the water and falling on the decks of large vessels. They dart rapidly backward by ejecting the water from their siphon or funnel.

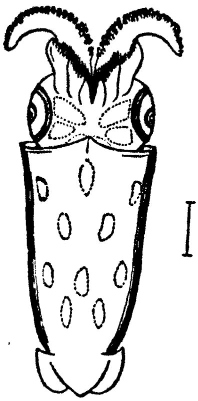


Fig. 219.—Same as Fig. 218, but farther advanced.

The Cephalopods are divided into two orders, according to the number of their gills.

Order 1. *Tetrabranchiata.* — This group, in which the gills are four in number, is represented by the *Nautilus*, the sole living representative of a number of fossil forms, such as *Orthoceras, Goniatites* and *Ammonites.*

Nautilus pompilius Linn. (Fig. 222), and *Nautilus umbilicatulus* are the only survivors of about 1500 extinct species of the order.

Order 2. *Dibranchiata.* — The *Dibranchiates* are so called from possessing but two gills, while the *Tetrabranchiates* had, as in *Nautilus*, numerous unarmed tentacles; these are now represented by ten (*Decapoda*). or eight (*Octopoda*) arms, provided with numerous suckers. To the ten-armed forms belong *Spirula*, a diminutive cuttle, with

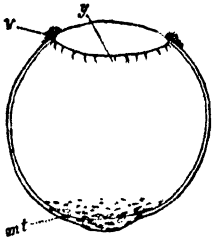


FIG. 220.

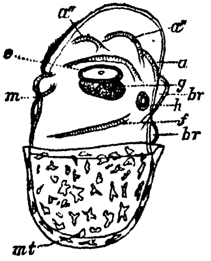


FIG. 221.

Fig. 220.—Development of an unknown cuttle-fish. *v*, velum; *y*, yolk; *mt*, mantle beginning to develop.

Fig. 221.—The same, much farther advanced. *a*, *a'*, *a''*, arms; *m*, mouth; *br. br*, gills; *f*, funnel; *h*, ear; *g*, optic ganglion; *mt*, mantle, the dotted line ending in a chromatophore.—After Grenacher.

an internal coiled shell. The shells of *Spirula Peronii* Lamarck are rarely thrown ashore on Nantucket; it lives upon the high seas. The extinct Belemnites was provided with an air-cavity (phragmocone) with a straight shell, the "thunderbolt" fossil. Allied to *Loligo* and *Ommastrephes,* are gigantic cuttle-fishes which live in mid-ocean, but whose remains

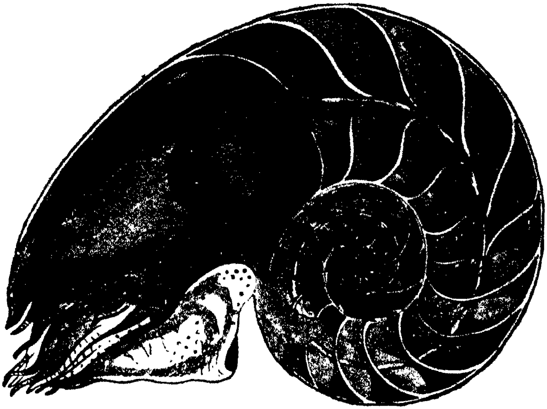


Fig. 222.—Pearly Nautilus, *N. pompilius.* Seen in section showing the chambers and siphuncle. **Half natural size.—From** Tenney's Zoology.

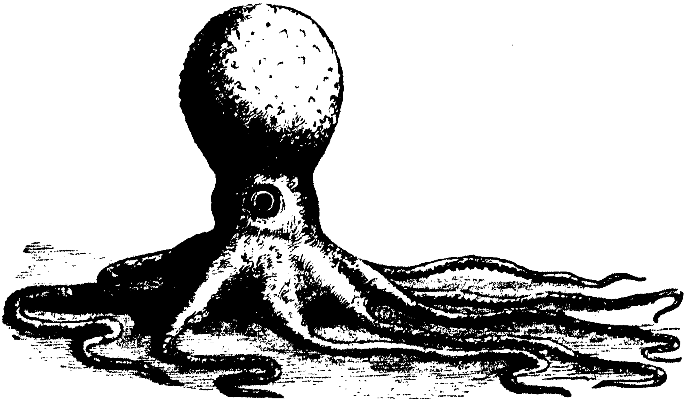


Fig. 223.—Poulpe or Common Octopus of **Brazilian Coast.**

have been found at sea, or cast ashore at Newfoundland and the Danish coast; or their jaws occur in the stomach of sperm whales, as squid of all sizes form a large proportion of the food of sperm whales, dolphins, porpoises, and other Cetaceans provided with teeth. The largest cuttle-fish known is *Architeuthis princeps* Verrill, the body of which must be about six and a half metres (nineteen feet) in length, and nearly two metres (five feet, nine inches) in circumference. The two longer arms are 9 metres long. *Architeuthis monachus* Steenstrup has a body about two metres (seven feet) long, and the two longer arms seven metres (twenty-four feet) long. A still larger individual was estimated by Verrill to be in total length about fourteen metres (forty-four feet). It is sometimes thrown ashore on the coast of Newfoundland and Labrador, and in one instance attacked two men in a boat.

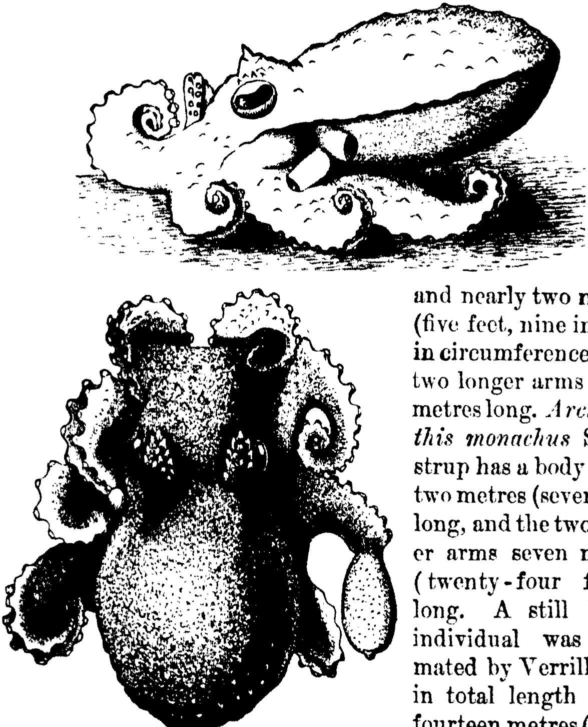


Fig. 224.—*Octopus Bairdii*, natural size, dorsal and lateral view. Gulf of Maine.—After Verrill.

The *Octopus* (Fig. 223) and *Argonauta* represent the eight-armed forms.

Those weird, horrifying creatures, the *Octopi*, are very soft-bodied, and live on shore just below or at low-water mark, or in deeper water. They have no shell or pen. *Octopus punctatus* Gabb expands 4½ metres (14 feet) from tip to tip of the outstretched arms. They are brought of this size into the markets of San Francisco, where they are eaten by Italians and Chinese. An Indian woman at Victoria, Vancouver Island, in 1877, was seized and drowned by an Octopus, probably of this species, while bathing on the shore. Smaller species on coral reefs sometimes seize collectors or natives, and fastening to them with their relentless suckered arms tire and frighten to death the hapless victim. *Octopus Bairdii* Verrill (Fig. 224) inhabits the Gulf of Maine at from fifty to one hundred fathoms.

The *Argonauta*, or paper nautilus, has a beautiful, delicate shell. *A. argo* lives in the Mediterranean, but in rare cases has been thrown ashore at New Jersey and Florida. The animal lives in the shell, but is not permanently attached to it, the shell not being chambered, and holds on to the sides by the greatly expanded terminations of two of its arms, which secrete the shell. The males are very small, not more than five centimetres (one inch) in length. During the reproductive season the third left arm becomes larger and different in form from the others, and becoming encysted is finally detached from the body, and deposited by the male within the mantle-cavity of the female, where the eggs in a way unknown are fertilized by the spermatic bodies. The free arm was supposed originally to be a parasitic worm, and was described under the name of *Hectocotylus*.

The living species of Cephalopods have a wide geographical range, and a high antiquity, the earliest forms appearing in the Lower Silurian Period, while the type culminated in the Liassic, Jurassic and Cretaceous Periods.

CLASS III.—CEPHALOPODA.

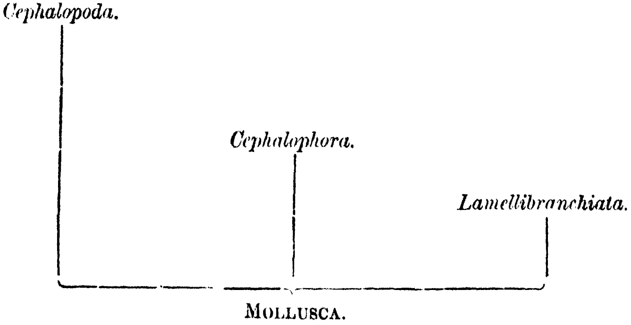
Mollusks with the head-lobe divided into arms, usually provided with suckers ; eyes more highly organized than in any other invertebrates ;

nervous ganglia much concentrated and protected by an imperfect cartilaginous capsule; pharynx armed with two teeth like a parrot's beak, besides an odontophore. Sexes distinct. Usually development is direct, with no metamorphosis; segmentation of the yolk partial, and a primitive streak is present as in birds and reptiles.

Order 1. *Tetrabranchiata.*—With four gills. (Nautilus, living; Orthoceras, Goniatites, Ammonites, extinct.)

Order 2. *Dibranchiata.*—With two gills. (Spirula, Belemnites, extinct, Sepia, Architeuthis, Loligo, Ommastrephes, Octopus Argonauta.)

TABULAR VIEW OF THE CLASSES OF MOLLUSCA.



Laboratory Work.—The cuttles are not easy to dissect. A horizontal section through the head will show the relations of the cartilaginous capsule to the brain, optic nerves and eyes. The nervous ganglia can only be traced after tedious dissection. To study the viscera freshly-killed specimens are quite essential.

CHAPTER VII.

BRANCH VII.—ARTHROPODA (CRUSTACEANS AND INSECTS).

General Characters of Arthropods.—To this group belong those Articulates which have jointed appendages, *i. e.*, antennæ, jaws, maxillæ (or accessory jaws), palpi, and legs arranged in pairs, the two halves of the body thus being more markedly symmetrical than in the lower animals. The skin is usually hardened by the deposition of salts, carbonate and phosphate of lime, and of a peculiar organic substance, called chitine. The segments (somites or arthromeres) composing the body are usually limited in number—twenty in the Crustaceans and eighteen in the insects—while each arthromere is primarily divided into an upper (tergum), lower (sternum), and lateral portion (pleurum). These divisions, however, cannot be traced in the head either of Crustaceans or insects. Moreover the head is well marked, with one or two pairs of feelers or antennæ, and from two to four pairs of biting mouth-parts or jaws, and two compound eyes; besides the compound eyes there are simple eyes in the insects. The germ is three-layered, and there is usually a well-marked metamorphosis. The Arthropoda are nearest related to the worms, certain Annelides, with their soft-jointed appendages (tentacles as well as lateral cirri) and well-marked head anticipating or foreshadowing the Arthropods. On the other hand, certain low parasitic Arthropods, as *Linguatula*, have been mistaken for genuine parasitic worms. So close are the affinities of the Vermes and Arthropods that they were by Cuvier united as a Branch *Articulata*, and while the Annelides and Arthropods may have had a common parentage, the recent progress in our knowledge of the worms, has led naturalists to discard the

Articulata of Cuvier as a heterogeneous assemblage of forms embracing at least three branches of the animal kingdom, namely, the *Vermes, Tunicata,* and *Arthropoda.*

The Arthropoda are divided into two well-defined classes, *i. e.,* the *Crustacea* with two body-regions, the head-thorax and abdomen (Fig. 225), and breathing through the body-walls or by external gills; and the *Insecta* (*Tracheata*), in which the arthromeres are grouped into three body-regions, *i. e.,* a head, thorax, and abdomen; and which breathe by internal air-tubes (tracheæ).

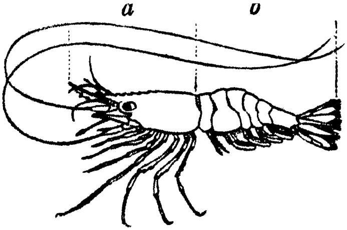
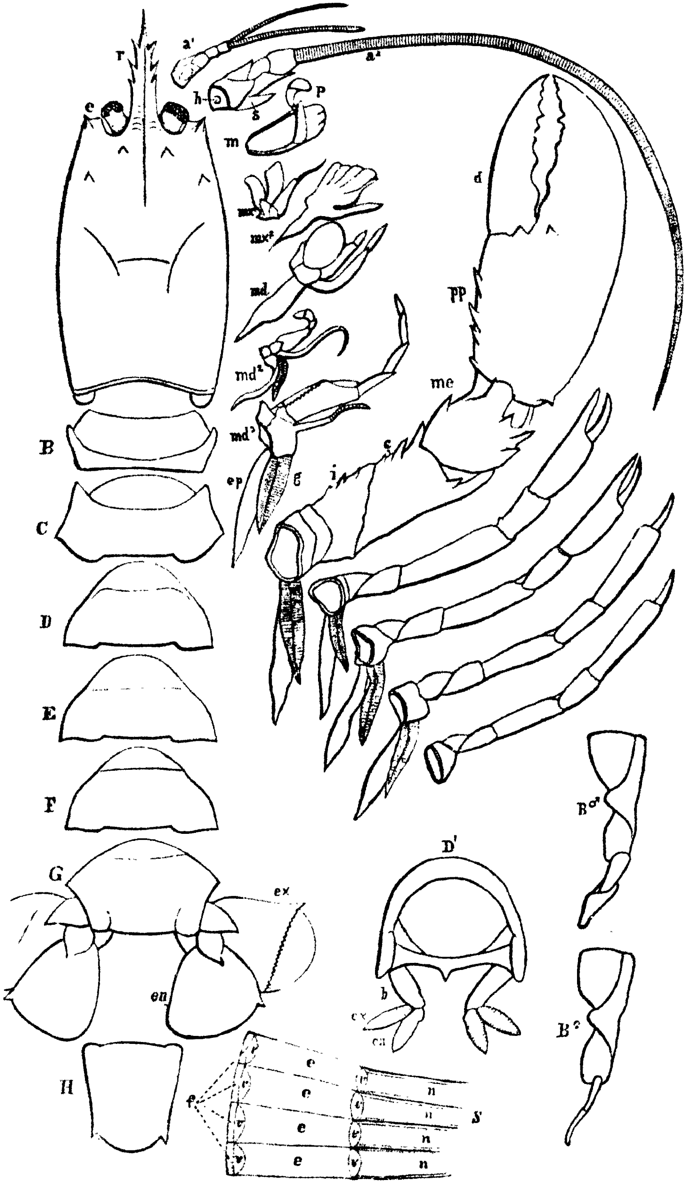


Fig. 225.—Shrimp, *Palæmonetes vulgaris.* *a*, cephalo-thorax; *b*, abdomen.

Class I.—Crustacea (*Water-fleas, Shrimps, Lobsters, and Crabs*).

General Characters of Crustaceans.—The typical forms of this class are the craw-fish, lobster, and crab, which the student should carefully examine as standards of comparison, from which a general knowledge of the class, which varies greatly in form in the different orders, may be obtained. The following account of the lobster will serve quite as well for the craw-fish, which abounds in the rivers and streams of the Middle and Western States.

The body of the lobster consists of segments (*somites, arthromeres*), which in the abdomen are seen to form a complete ring, *bearing a pair of jointed appendages,* which are *inserted between the sternum and tergum, the pleurum not being well marked in the abdominal segments.* The abdomen consists of seven segments. One of these segments (Fig 226 *D'*) should be separated from the others by the student, in order to observe the mode of insertion of the legs. Each segment bears but a single pair of appendages, and it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is a general rule that in the Arthropods each segment bears but a single pair of appendages. The abdominal feet are called "swimmerets;" they are narrow, slender, divided at the end into two or three lobes or portions, and are used for swimming, as well as in the female for carrying the eggs. The first pair are slender in the female (Fig. 226, B ♀) and not divided, while in the male (Fig. 226, B ♂) they are much larger, and modified to serve as intromittent organs. The sixth segment (Fig. 226, *G*) bears broad paddle-like appendages, while the seventh segment, forming the end of the body and called the "telson," bears no appendages. It represents mostly the tergum of the segment. Turning now to the cephalo-thorax, we see that there are two pairs of antennæ, the smaller pair the most anterior; a pair of mandibles with a palpus, situated on each side of the mouth; three pairs of maxillæ or accessory jaws, which are flat, divided into lobes, and of unequal size; two pairs of foot-jaws (maxillipedes), which differ from the maxillæ in having gills like those in the five following pairs of legs. There are thus thirteen pairs of cephalo-thoracic appendages, indicating that there are thirteen corresponding segments; these, with the seven abdominal segments, indicate that there are twenty segments in a typical Crustacean. By some authors the eyes are regarded as homologues of the appendages, but in early life they are seen to be developed on the second antennal segment, as they are in the lower Crustacea. They are simply modified epithelial cells of the body-walls, as in the eyes of the lower invertebrates. The ears are situated in the smaller antennæ (Fig. 226, *a'*). In the second or larger antennæ are situated the openings of the ducts (Fig. 226, *h*) leading from the "green glands," while the external openings of the oviducts are situated, each on one of the third pair of thoracic feet.

It is impossible, except by counting the appendages themselves, to ascertain with certainty the number of segments in the cephalo-thorax, the dorsal portion of the segments being more or less obsolete, but the carapace, or shield of the head-thorax, may be seen, after close examination, to represent the second antennal and mandibular segments, and is so developed as to cover the other cephalo-thoracic segments, thus exemplifying, in an interesting way, Audouin's law of the development of one segment or part of a segment at the expense of adjoining parts or segments; this law, so universal in the Arthropods, as well as throughout the animal kingdom, also applies to the appendages.

The same parts are to be found in the crab, but in a modified form, owing to the development or transfer of the weight of the organization headwards; in other words, the crab is more cephalized than the lobster; this is seen in the small abdomen folded under the large, broad cephalo-thorax, and in the greater concentration headwards of the nervous system of the crab.

To study the internal structure of the lobster, the dorsal surface of the carapace and of each abdominal segment should be removed; in so doing the *hypodermis* or soft inner layer of the integument is disclosed; it is usually filled with red pigment cells. The dorsal vessel, or heart, lies under the hypodermis of the carapace, this being an irregular hexagonal mass surrounded by a thin membrane (pericardium) with four valvular openings for the ingress of the venous blood. The colorless, corpusculated blood is pumped by the heart backwards and forwards through three anterior arteries, one median and two lateral, the median artery passing towards the head over the large stomach, and the two lateral, or hepatic arteries, passing to the liver and stomach. From the posterior angle of the heart arise two arteries; the upper, a large median artery (the superior abdominal), passes along the back to the end of the abdomen, sending off at intervals pairs of small arteries to the large masses of muscles filling the abdominal cavity; the lower is the second or sternal artery, which connects with one extending along the floor of the body near the thoracic ganglia of the nervous cord. The arteries become, at least in the liver, finely subdivided, forming a mass of capillaries. There are no veins such as are present in the Vertebrates, but a series of venous channels or sinuses, through which the blood returns to the heart. There is a large vein in the middle of the ventral side of the body.

The blood is driven by the heart through the arteries, and a large part of it, forced into the capillaries, is collected by the ventral venous sinus, and thence passing through the gills, where it is oxygenated, returns to the heart.

The gills are appendages of the three pairs of maxillipedes and the five pairs of feet, and are contained in a chamber formed by the carapace ; the sea-water passing into the cavity between the body and the free edge of the carapace is afterwards scooped out through a large opening or passage on each side of the head, by a membranous appendage of the leg, called the "gill-bailer" (*Scaphognathite*).

The digestive system consists of a mouth, opening between the mandibles, an œsophagus, a large, membranous stomach, *with very large teeth for crushing the food within the large or cardiac portion, while the posterior or pyloric end forms* a strainer through which the food presses into the long, straight intestine, which ends in the telson. The liver is very large, dark green, with two ducts emptying on each side into the junction of the stomach with the intestine.

The nervous system consists of a brain situated directly under the base of the rostrum (supraœsophageal ganglion), from which a pair of optic nerves go to the two eyes, and a pair to each of the four antennæ. The mouth-parts are supplied with nerves from the infraœsophageal ganglion, which, with the rest of the nervous system, lies in a lower plane than the brain. There are behind these two ganglia eleven others ; the cephalo-thoracic portion of the cord is protected above by a framework of solid processes, which forms, as it were, a "false-bottom" to the cephalo-thorax ; this has to be carefully removed before the nervous cord can be laid bare. A sympathetic nerve passes around each side of the œsophagus and distributes branches to the stomach.

The nerves of special sense are the optic and auditory nerves. The eyes are compound, namely, composed of many simple eyes, each consisting of a *cornea* and *crystalline cone*, connected behind with a long, slender *connective rod*, uniting the cone with a spindle-shaped body resting on or against an expansion of a fibre of the optic nerve, and is ensheathed by a retina or black pigment mass (Fig. 226 *s*).

Though as many images may be formed in each eye as there are distinct crystalline cones, yet, as in man with his two eyes, the effect upon the lobster's mind is probably that of a single image.

The lobster's ears are seated in the base of the smaller or first antennæ; they may be detected by a clear, oval space on the upper side; on laying this open, a large capsule will be discovered; inside of this capsule is a projecting ridge covered with fine hairs, each of which contains a minute branch of the auditory nerves. The sac is filled with water, in which are suspended grains of sand which find their way into the capsule. A wave of sound disturbs the grains of sand, the vibrations affect the sensitive hairs, and thus the impression of a sound is telegraphed along the main auditory nerve to the brain.

Organs of touch are the fine hairs fringing the mouth-parts and legs. The seat of the sense of smell in the Crustacea is not yet known, but it must be well developed, as nearly all Crustacea are scavengers, living on decaying matter. Crabs also have the power of finding their way back to their original habitat when carried off even for several miles.

The two large so-called "green glands" situated on each side within the head-thorax, and having an outlet at the base of each of the larger antennæ, are probably renal in their functions, corresponding to the kidneys of the vertebrate animals.

The ovaries and corresponding male glands, are voluminous organs, the testes being white, and the ovaries, when the lobster is about to spawn, being highly colored, usually pale green, and the ovarian eggs are quite distinct. The lobster spawns from March till November; the young are hatched with much of the form of the adult, not passing through a metamorphosis, as in most shrimps and crabs. They swim near the surface until about one inch long, when they remain at or near the bottom.

The lobster probably moults but once annually, during the warmer part of the year, after having nearly attained its maturity, and when about to moult, or cast its tegument, the carapace splits from its hind edge as far as the base of the rostrum or beak, where it is too solid to separate. The lobster then draws its body out of the rent in the anterior part of the carapace. The claw—at this time soft, fleshy, and very watery—is drawn out through the basal joint, without any split in the old crust. In moulting, the stomach, with the solid teeth in the cardiac portion, is cast off with the old integument; why the stomach can thus be rejected is explained by the fact that the mouth, œsophagus, and stomach are continuous in early embryonic life with the epithelium forming the outer germ-layer, the mouth and anterior part of the alimentary canal being the result of an invagination of the ectoderm. The old skin is originally loosened and pushed away from the hypodermis, or under-layer, by the growth of temporary stiff hairs, which disappear after the skin is cast; the hairs, however, at least in the craw-fish, do not occur on the line of the facetted cornea, on the eye-stalk, or on the inner lamellæ of the fold of the carapace over the gill-opening.

The student is now prepared to understand the descriptions of the types of the different orders. The Crustacea may be divided into two series of orders, or two subclasses, *i. e.*, the normal Crustacea, in large part composed of species now living, though containing numerous palæozoic forms, for which we would propose the term *Neocarida;* and the more generalized type of Crustacea, which abounded almost to the exclusion of other Crustacea, except the bivalved minute forms, in the Palæozoic age of the world, and which may be called the *Palæocarida.* They are represented by the fossil Trilobites and *Eurypterida,* and the only surviving member, the King-Crab (*Limulus*).

We will now study the orders of *Neocarida,* treating of them as heretofore in the ascending order.

Order 1. *Cirripedia.*—The barnacles would, at a first glance, hardly be regarded as Crustacea at all, so much modified is the form, owing probably to their fixed, parasitic mode of life. Indeed they were formerly placed among the Mollusca, until, in 1836, Thompson found that the young barnacle was like the larva of other low Crustacea (*Copepoda*). The barnacle is, as in the common sessile form

(Fig. 227), a shell-like animal, the shell composed of several pieces, with a multivalve, conical movable lid, having an opening through which several pairs of long, many-jointed, hairy appendages are thrust, thus creating a current which sets in towards the mouth. The common barnacle (*Balanus balanoides* Stimpson) abounds on every rocky shore from extreme high-water mark to deep water, and the student can, by putting a group of them in sea-water, observe the opening and shutting of the valves and the movements of the appendages or "cirri."

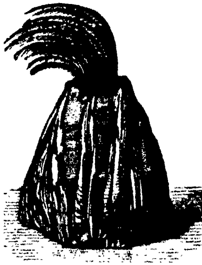

Fig. 227.—A barnacle. *porcatus.* Natural size.

The structure of the barnacle may best be observed in dissecting a goose barnacle (*Lepas fascicularis* Ellis and Solander, Fig. 228). This barnacle consists of a body (*capitulum*) and leathery peduncle. There are six pairs of jointed feet, representing the feet of the *Cyclops* (Fig. 236). The mouth, with the upper lip mandibles (*B*, 1), and two pairs of maxillæ, will be found in the middle of the shell. A short œsophagus (according to J. S. Kingsley, whose account we are using) leads to a pouch-like stomach and tubular intestine. This form, like most barnacles, is hermaphroditic, the ovary (*A*, *o*) lying at the bottom of the shell, or in the pedunculated forms in the base of the peduncle, while the male gland (*t*) is either close to or some distance from the ovary. There is also at the base of the shell, or in the peduncle when developed, a cement-gland, the secretion of which is for the purpose of attaching the barnacle to some rock or weed.

While the sexes are generally united in the same individual, in the genera *Ibla* (Fig. 229) and *Scalpellum* (Figs. 230, 231), besides the normal hermaphroditic form, there are females, and also males called "complementary males," which are attached parasitically both to the females and the hermaphroditic forms, living just within the valves or fastened to the membranes of the body. These complemental males are degraded, imperfect forms, with sometimes no mouth or digestive canal. The apparent design in nature of their different sexual forms is to effect cross fertilization. The eggs pass from the ovaries into the body-cavity, where they are fertilized, and remain for some time. They pass through a morula condition, a suppressed gastrula or two-layered state, and hatch in a form called a *Nauplius*, from the fact that the free-swimming larva of the Entomostraca

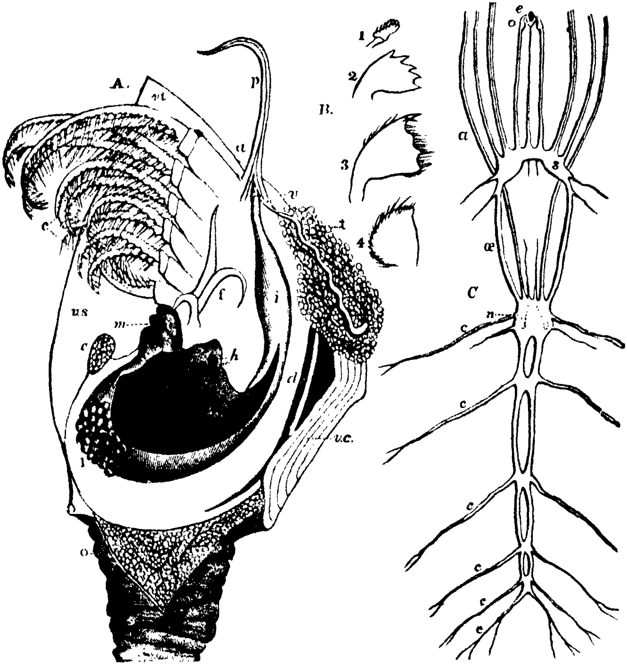

Fig. 228.—Anatomy of *Lepas fascicularis*. *A*. *c*, six pairs of legs or cirri; *f*, filamentary appendages; *m*, mouth; *s*, stomach; *h*, openings of the liver (*l*) into the stomach, which is represented as laid open; *i*, intestine; *a*, vent; *t*, testis; *v*, vasa deferentia, one cut off; *p*, male appendage; *o*, ovary; *e*, adductor muscle connecting the two basal valves; *vs*, scutal valve; *vc*, carinal valve; *vt*, tergal valve. Enlarged twice.

B. 1. palpus; 2, mandibles; 3 and 4, first and second maxillæ.

C. Nervous system. *s*, brain, sending the optic nerves to the rudimentary eye (*e*), each optic nerve having an enlargement near the eye, *i. e.*, the ophthalmic ganglion (*o*); between *o* and *a* are the nerves which go to the peduncle; *a*, nerve sent to the *adductor scutorum*; *α*, commissure between the supra- and infraœsophageal ganglia (*n*); *c*, *c*, *c*, *c*, *c*, *c*. nerves to each of the six feet. Enlarged four times.—After Kingsley.

was at first thought to be an adult Crustacean, and described under the name of *Nauplius.* The Nauplius of the genuine barnacles (Fig. 232) has three pairs of legs ending in long bristles, with a single eye, and a pair of antennæ, the body ending in front in two horns, and posteriorly in a long caudal spine. After swimming about for a while, the Nauplius attaches itself to some object by its antennæ, and now a strange transformation results. The body is enclosed by two sets of valves, appearing as if bivalved, like a *Cypris* (Fig. 233); the peduncle grows out,

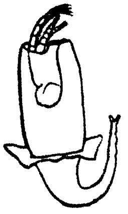
Fig. 229 — *Ibla.* [illegible]mentary male, enlarged.— After Darwin.

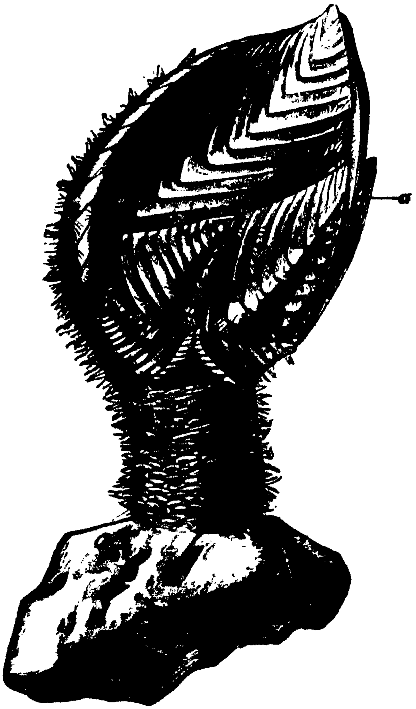

Fig. 230.—*Scalpellum regium.* *a*, complementary male, lodged within the valves.—After Wyville-Thompson.

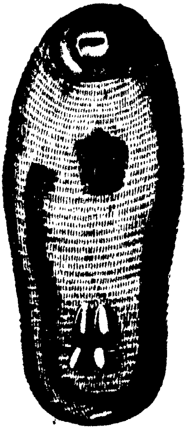
Fig. 231.—Complementary male of *Scalpellum regium*, greatly enlarged.—After Wyville-Thompson.

concealing the rudimentary antennæ, and the feet grow smaller, and eventually the barnacle-shape is attained. The common barnacle (*Balanus balanoides*) attains its full size, after becoming fixed, in one season, *i. e.*, between the first of April and November.

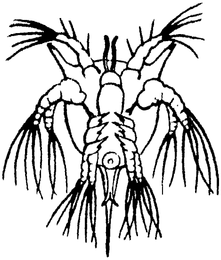

Fig. 232.—Nauplius of *Balanus balanoides*, much enlarged.

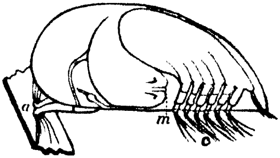

Fig. 233.—Pupa of *Lepas*, much enlarged.—After Darwin.

Still lower than the genuine barnacles are the root-barnacles or *Rhizocephala*, represented by *Peltogaster* (Fig. 234) and *Sacculina* (Fig. 235), in which the young is a more simple *Nauplius* form, like the young of the *Entomostraca*, while the adult is a simple sac, containing no digestive organs or nerves. From the feet of the young grow out, after the animal becomes sessile, long root-like filaments, which ramify in the body of the crab, to which these animals are firmly anchored. We can conceive of no lower, more degraded Crustacean than these root-barnacles, the only signs of life being the powerful contractions of the roots and an alternate expansion and contraction of

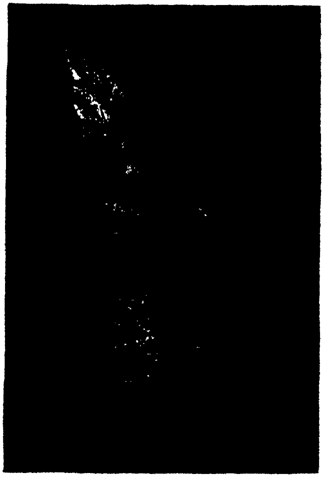

Fig. 234. — *Peltogaster curvatus*, enlarged 1½ times, beneath the larva or Nauplius of Parthenopea, enlarged about 200 times.—From Brehm's Thierleben.

the body, forcing the water into the brood-cavity, and again expelling it through a wide orifice. These root-barnacles recall the Trematode worms, though the latter are much more highly organized. An allied form (*Cryptophialus minutus*) undergoes the larval or Nauplius stage in the egg, hatching in the pupa condition, while another form (a species of *Peltogaster?*) also leaves the egg in the pupa form

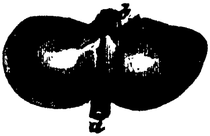

Fig. 235.—*Sacculina carcini*, natural size. *a*, base of root; *b*, opening for exit of eggs.—From Brehm's Thierleben.

Order 2. *Entomostraca* (Water-fleas).—The type of this group is *Cyclops* (Fig. 236, *C. quadricornis*, see also Fig. 237) in which the body is pear-shaped, with a single bright eye in the middle of the head; two pairs of antennæ, used for swimming as well as sense-organs; biting mouth-parts, and with short legs. The sexes are distinct, the females swimming about with two egg-masses attached to the base of the abdomen. The young is a Nauplius, much like that represented in Fig. 234, the mouth-organs, the legs and abdominal segments arising after successive moults, until the adult form is attained. Allied to Cyclops is *Canthocamptus cavernarum* Packard (Fig. 238), an eyed species, living in Willie's Spring, in Mammoth Cave.

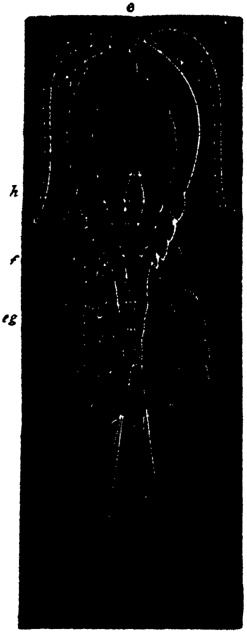

Fig. 236.—*Cyclops*. *e*, eye; *h*, heart; *eg*, eggs; *f*, feet.—After Clark.

Many *Entomostraca* are parasitic, and consequently undergo a retrograde development, losing the jointed structure of the body, the appendages being more or less aborted, while the body increases greatly in size. Such are the fish-lice, represented by the *Lernæa* of the cod.

In *Lerneonema radiata* Steenstrup and Lütken (Fig. 239), we find the lowest term in the series of degradational forms of this order. The mouth-parts are here converted into five roots, radiating from the head; the body is not segmented, and ends in two long egg-masses.

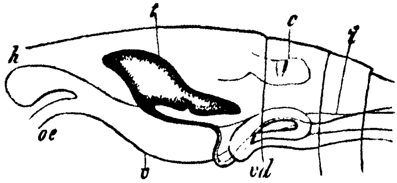

Fig. 237.—Intestine and testis (*t*) of a copepod (*Pleuroma*), side view. *œ*, œsophagus; *v*, stomach; *h*, blind sac leading from the stomach; *i*, intestine; *c*, heart; *vd*, coiled vas deferens.—After Claus, from Gegenbaur.

In *Penella* (Fig. 241) the body is cord-like, buried in the flesh of the sun-fish or sword-fish, etc., the females having two long, string-like egg-sacs. The specimen figured was taken from a sword-fish off Portland, Maine.

In *Lernæa branchialis* Linn. of the gills of the cod, the body is thicker, the root-like appendages grow deep into the flesh of its host, like twisted and gnarled roots, while the shapeless sac-like body is filled with eggs.

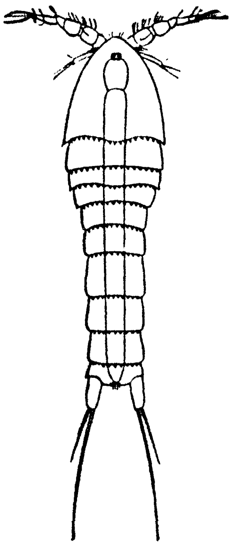

Fig. 238.—*Canthocamptus cavernarum* of Mammoth Cave, much

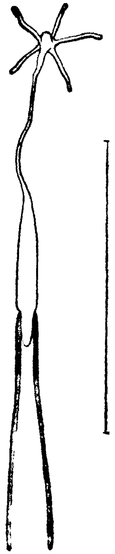

Fig. 239.—Fish-louse of

—After Verrill.

In *Actheres*, we ascend a step higher in the perfection of organs; the creature is attached by a pair of

form a sucker, the antennæ are present, though rudimentary, while the abdomen is faintly segmented. *A. Carpenteri* Packard (Fig. 240) lives on the trout in Colorado.

The highest members of the group of sucking Entomostraca are *Caligus* and *Argulus*, in which the body is segmented, with antennæ and free mouth-parts and legs; the latter genus with compound eyes. *Caligus curtus* Müller lives on the cod, and *Argulus alosæ* Gould on the alewife.

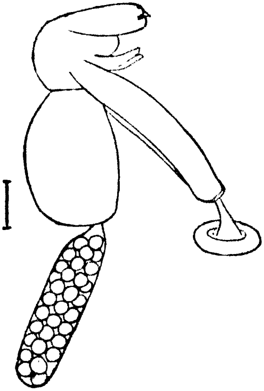

Fig. 240.—Actheres of the trout.

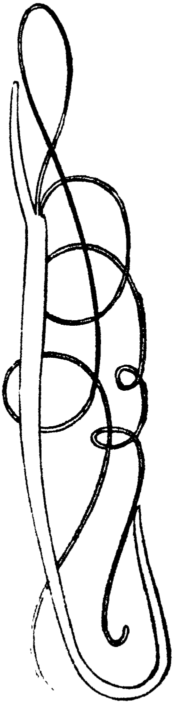

Fig 241.—Penella of the sword-fish, female.

Order 3. *Branchiopoda.*—This order includes such Crustacea as in the higher forms breathe by rather broad feet. There is a considerable range of form from the *Ostracoda*, represented by *Cypris*, in which the feet are much as in *Cyclops*, through *Daphnia* and *Sida* (Fig. 242) which represent the *Cladocera*, up to the Phyllopods. The suborder of *Ostracoda* (*Cypris*) are bivalved, the shell often thick. They have two eyes, two pairs of antennæ, a pair of mandibles with a jointed feeler (palpus) and a gill, and four pairs of feet, the second pair often carrying a small gill. The shells of certain species allied to *Cypris* abound in the lowest Silurian strata. The species live in fresh-water pools and in the ocean at various depths. They undergo no metamorphosis, the youngest stage being a shelled Nauplius.

The suborder *Cladocera* is represented by fresh and salt-water species. The higher forms are *Sida* and *Daphnia.* They are called water-fleas from their jerky motions. The eggs of *Daphnia* are borne about by the females in so-called brood-cavities on the back under the shell. There are two sorts of eggs, *i. e.*, the "summer" eggs, which are laid by asexual females, the males not appearing until the autumn, when the females lay the fertilized "winter" eggs, which are surrounded by a very tough shell. Dohrn observed the development of the embryo in the summer eggs. At first the embryo has but three pairs of appendages, representing the antennæ and one pair of jaws. It is thus comparable with the Nauplius of the Copepodous *Entomostraca,* and thus the Cladocera may be said to pass through a Nauplius stage in the egg.

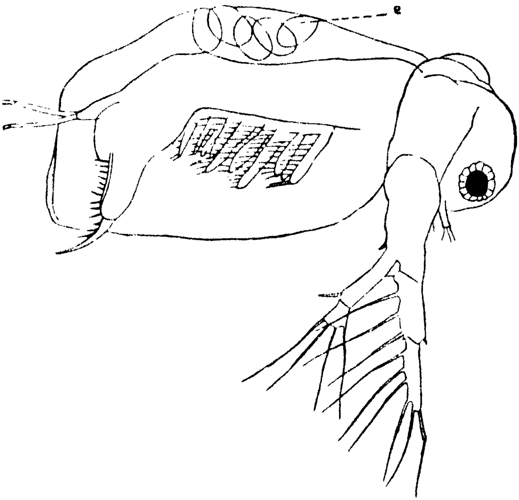

Fig. 242.—Sida. *e*, egg in brood-sac.

Afterwards more limbs grow out, until finally the embryo is provided with the full number of adult limbs, and hatches in the form of the mature animal, undergoing no farther change of form.

The members of the suborder *Phyllopoda* are more highly developed than any of the Crustacea mentioned, though, like the Ostracodes and Cladocera, the body is usually partly covered by a large carapace (the mandibular segment greatly developed), which is sometimes bent down, and opens and shuts by an adductor muscle, so that they resemble bivalve

Mollusca But they are especially characterized by the broad leaf-like feet, subdivided into lobes, and adapted for breathing as well as for swimming. The thorax merges insensibly into the abdomen. The number of body-segments varies greatly, there being sixteen in *Limnetis,* the simplest form, and sixty-nine in *Apus*, or three times the number present in the lobster, the segments thus being irrelatively repeated, a sign of inferiority. There is a pair of simple eyes consolidated into one as in *Limnetis* and *Limnadia*, or as in *Apus*, there is a pair of compound eyes, situated in the carapace, apparently on one of the antennal segments. In *Branchipus* and *Artemia* the compound eyes are stalked, an anticipation of the stalked eye of the lobster, etc., but the eye, it should be noticed, is not developed from a separate segment, but from one of the two antennal segments. All the members of this order hatch in the Nauplius form, the three pairs of appendages of the larva, representing the two pairs of antennæ and the mandibles of the adult. The species live in pools of fresh water liable to dry up in summer; they lay eggs which drop to the bottom, and show great vitality, withstanding the heat and dryness after the water has evaporated; the young hatching after the rains refill the pools or ditches.

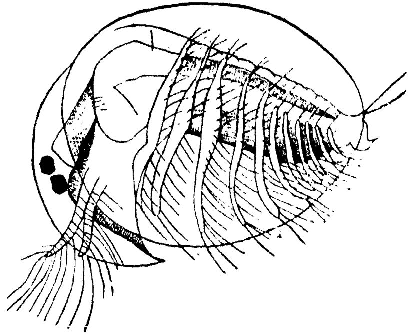

Fig. 243.—*Limnetis Gouldii*, much enlarged.—After Burgess.

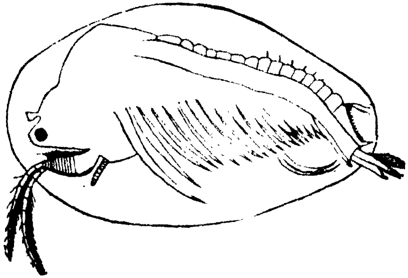

Fig. 244.—Limnadia Agassizii, enlarged.

This suborder presents a beautiful series of increasingly complex forms, as we ascend from *Limnetis* to *Branchipus.* In *Limnetis* the bivalve shell encloses the animal, and is the size of a small flattened pea. There are from ten to twelve feet-bearing segments. *L. Gouldii* Baird (Fig. 243) is very rare in Canada and New England. The shell of *Limnadia* is thin, oval, and there are from eighteen to twenty-six feet-bearing segments. *L.* (*Eulimnadia*) *Agassizii* Packard (Figs. 244 and 245) inhabits pools in Southern New England. The shell of *Estheria* (Fig. 246, *Estheria Belfragei* Packard) is sometimes mistaken for that of the fresh-water mollusks *Cyclas* and *Pisidium.* The males of the foregoing genera have the first pair of feet modified to form large claspers (Fig. 245).

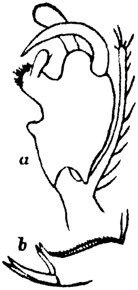

Fig. 245.—Foreleg of male *Eulimnadia complexima.* *a*, hand; *b*, end of body.

In *Apus* the abdomen projects beyond the large carapace, and ends in two long many-jointed appendages. There are about sixty pairs of feet, each foot divided into several leaf-like lobes, wherein respiration is carried on.

These Phyllopods usually swim upon their backs, as in the species of *Branchipus.* The females chiefly differ from the males in the presence of an orbicular egg-sac on the eleventh pair of feet, the sac being a modification of two of the lobes of the feet, and containing but a few eggs. *Apus æqualis* Packard (Fig. 247, Fig. 249 *A*, represents the larva of a European *Apus*) inhabits pools in the western plains. *Lepidurus* differs from *Apus* in having the telson spoon-shaped instead of square. *L. Couesii* Packard (Fig. 248) occurs on the Rocky Mountain plateau in Utah and Montana. It is an interesting fact in zoo-geography that there are no species of *Apus* and *Lepidurus* east of the western plains. *Apus* has been found by Siebold to reproduce parthenogenetically.

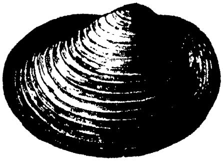

Fig. 246.—Shell of *Estheria Belfragei*, enlarged three times.

The various species of *Branchipus* and *Artemia* have no carapace, the mandibular segment being small and not overlapping the segments behind it. The second antennæ are large and in the male adapted for clasping. In *Thamnocephalus* (Fig. 250, *T. brachyurus* Packard, from Kansas) there is a singular shrub-like projection of the front of the head, and the abdomen is spatulate or spoon-shaped at the end. *Branchinectes Coloradensis* Pack. (Fig. 251) is a Rocky Mountain form. The brine-shrimp, *Artemia*, lives only in brine-vats or in the salt lakes of the West and of Southern Europe. *Artemia gracilis* Verrill (Fig. 252) has thus far only been found in tubs

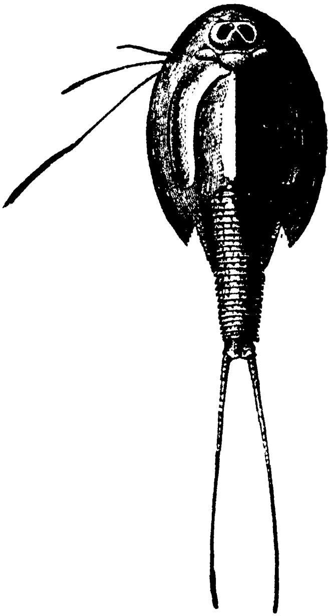
Fig. 247.—*Apus æqualis*, natural size.

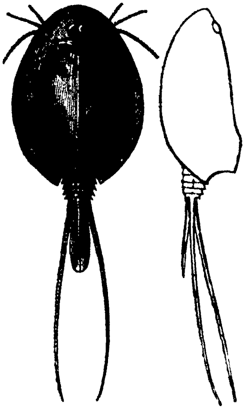
Fig. 248.—*Lepidurus Couesii*, side and dorsal view, natural size.

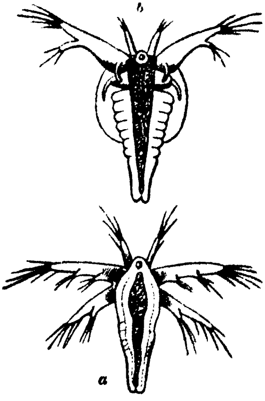

Fig. 249.—*a*, Larva of *Apus cancriformis*. — After Zaddach. *b*, Nauplius of *Artemia salina* of Europe.

of concentrated salt water on railroad bridges in New England. *Artemia fertilis* Verrill abounds in Great Salt Lake.

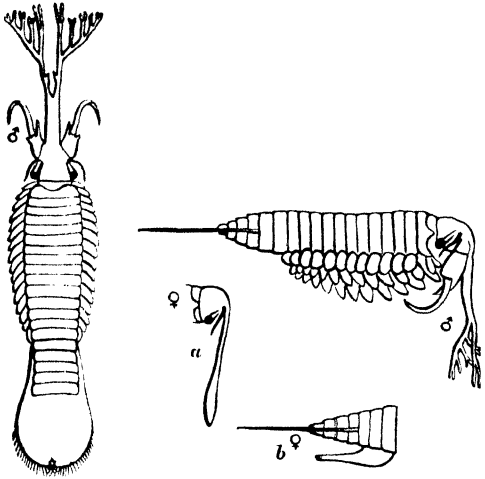

Fig. 250.—*Thamnocephalus platyurus*, male, natural size, side and front view. *a*, head of the female; *b*, end of the body of the female, showing the ovisac.

They may often be seen swimming about in pairs, as in Fig. 253. This species has a Nauplius young like that of

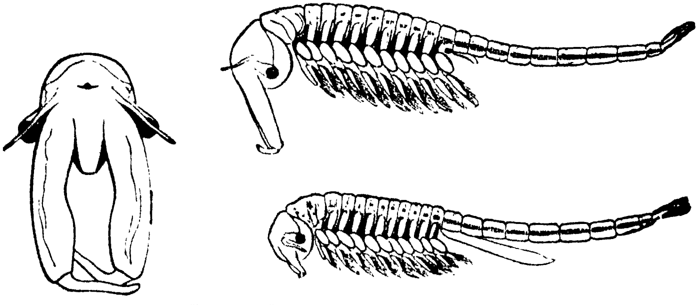

Fig. 251.—*Branchinectes Coloradensis* Pack.

the brine-shrimp of Europe (Fig. 249 *b*). It is a significant fact, bearing on the question of the origin of species, that, according to Schmankiewitsch, *Artemia* may change its form, the change being induced by the greater or less saltness of the water. *Artemia* produces young by budding (parthenogenesis) as well as from eggs. A species observed near Odessa produced females alone in warm weather; and only in water of medium strength were males produced. The eggs of *Artemia fertilis* have been sent in moist mud from Utah to Munich, Germany, and specimens raised from the eggs by Siebold, proving the great vitality of the eggs of these Phyllopods, a fact paralleled by the similar vitality of the eggs of the king-crab. Fig. 249 *b* represents the Nauplius of the European brine-shrimp.

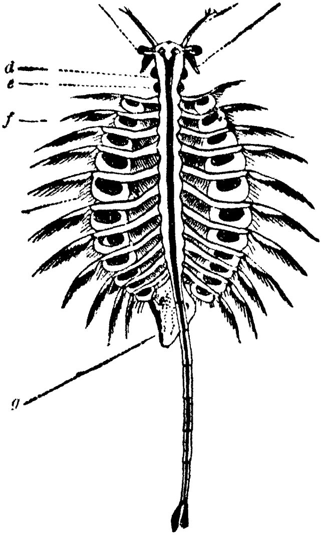

Fig. 252.—Brine-shrimp, *Artemia gracilis*, enlarged. *a*, first antenna; *b*, second antenna or clasper; *c*, stalked eye; *d*, *e*, jaws; *f*, a foot; *g*, egg-sac. —After Verrill.

Order 4. — *Tetradecapoda.*— To this order belong the sow-bugs (*Isopoda*) and the beach-fleas (*Amphipoda*). In these Crustacea there is no cephalothorax, but the head is small, bearing two pairs of antennæ, and a pair of jaws, and three pairs of maxillæ. The thorax is continuous with the abdomen. Respiration is performed by lamellate or leaf-like gills on the middle feet in the Amphipods, or on the hinder abdominal feet in the Isopods. The lowest Isopods are parasitic, they graduate into the Amphipods, and the higher Amphipods are connected with the shrimps (*Decapoda*) through a group (probably a suborder) of synthetic forms (*Palæocaris*, *Acanthotelson* and *Gampsonyx*, Fig. 254) such as are found in the coal formation of Illinois

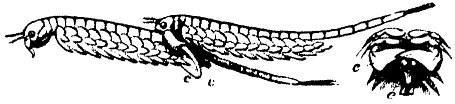

Fig. 253.—*Artemia fertilis* from Great Salt Lake. *e*, egg-sac; *c*, male claspers.

and Europe, which may be called *Anthracarida*, and which have antennæ and tails like shrimps, but the body and limbs like Amphipods. In the Isopods the body is flattened and the head rather broad.

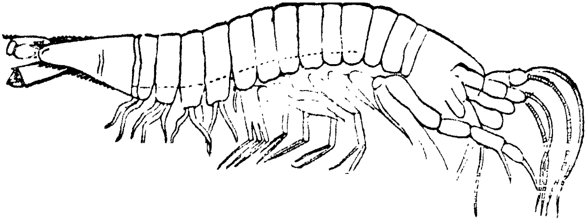

Fig. 254.—*Gampsonyx fimbriatus* of European coal measures, 2½ times natural size.

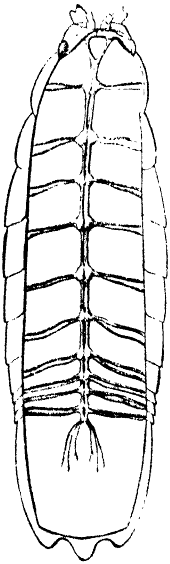

Fig. 255.—Nervous of *Idotæa ir-* —Drawn by J. S. Kingsley.

Fig. 256 is a dorsal view of *Serolis Gaudichaudi* Audouin and Edwards, with the *two pairs of antennæ and pointed sides of each thoracic segment, dissected to show the nervous system*, the two pairs of antennal nerves; the optic nerves (*op*) sent to the compound eyes. Fig. 257 represents a transverse section of the body, showing the mode of insertion of the legs, and the equality in the tergal and sternal sides of the body. Fig. 259 represents a gill. In the common pill-bug (*Porcellio*) aërial respiration is performed by respiratory cavities situated in the abdomen. In *Tylos* similar cavities are filled with a multitude of branching cœca, serving for aërial respiration, thus anticipating the tracheary system of insects. The nervous system is quite simple. (Fig. 255, *Idotæa*, and Fig. 256, that of *Serolis*.) The digestive canal is straight, consisting of a short œsophagus, a membranous stomach, and usually a short tubular intestine; the liver consisting of several short cœca. In *Serolis Gaudichaudi* the stomach is somewhat pear-shaped, widest behind, extending a little behind the middle of the body. The intestine is about one half as wide as the stomach.

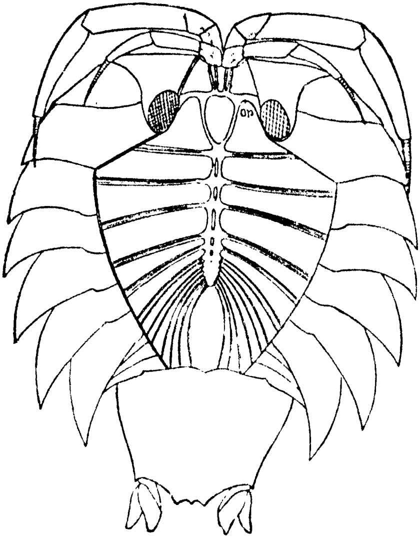

Fig. 256.—Dissection of *Serolis* to show the nervous system.—Dissected and drawn by J. S. Kingsley.

There is no cœcal enlargement, and no "urinary" tubes. The sexes are distinct. The young are hatched in the form of the adult, there being no metamorphosis.

The development of the pill-bug, *Oniscus murarius*, is probably typical of that of most Tetradecapods and Decapods (Bobretzky). The first change after fertilization is the origin of the formative or primitive blastodermic cells at one

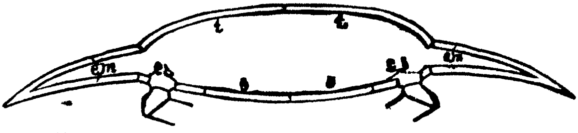

Fig. 257.—Transverse section of *Serolis*. *t*, *t*, tergum; *s*, *s*, sternum; *em*, epimerum; *es*, episternum, at insertion of the legs.—Prepared and drawn by J. S. Kingsley.

pole of the egg. This single cell subdivides, its products forming the "blastodermic disk" or outer germ-layer, the segmentation of the yolk being partial. The third (innermost) and middle germ-layers next arise (the same processes go on in certain shrimps, viz.: *Crangon* and *Palæmon*). The intestine is formed by an in-pushing of the outer germ-layer. The limbs now bud out, the result of the pushing out of the outer germ-layer (ectoderm). The nervous cord arises from the ectoderm; the large intestine originates in the yolk-sac, its epithelium first appearing in the liver-sac. The heart is the last to be formed. Externally the antennæ in *Oniscus* and also *Asellus* are the first to bud out; the remaining appendages of the head and thorax arise contemporaneously, and subsequently the abdominal feet. The abdomen in the Isopods is curved upwards and backwards, while in the embryo Amphipods it is bent beneath the body.

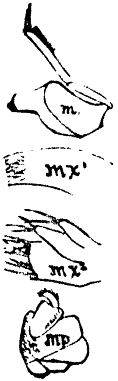

Fig. 258.—Mouth-parts of *Serolis*. *m*, mandible; *mx'*, first maxilla; *mx''*, second maxilla; *mp*, maxillary palpus.—Drawn by J. S. Kingsley.

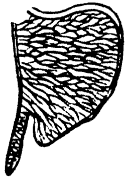

Fig. 259.—A gill of *Serolis*.—Drawn by J. S. Kingsley

The development of the Amphipods or beach-fleas is nearly identical with that of the Isopods. The eggs of certain species undergo total segmentation, while those of other species of the same genus (Gammarus) partially segment, as in the spiders, and in a less degree the insects.

Standing next below *Cymothoa*, which is of the general Isopod shape, but which lives parasitically on the tongue and other parts of fishes, but which from their parasitic habits become slightly changed in form, the females especially, sometimes becoming blind, is the family of which *Bopyrus* is a representative. The females (Fig. 262) are parasitic under the carapace of various shrimps. In *B. pandalicola* Packard n. sp., the females are many times larger than the males; the ventral side of the body is partly aborted, having been absorbed by its pressure against the carapace of its host, which is swollen over it; it retains its position by

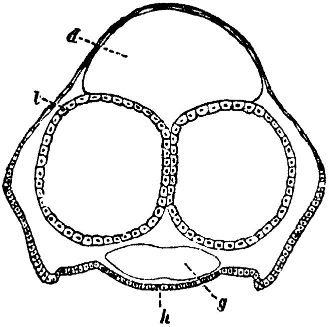

FIG. 260.

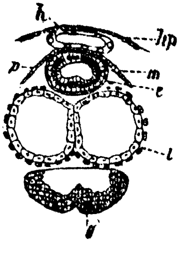

FIG. 261.

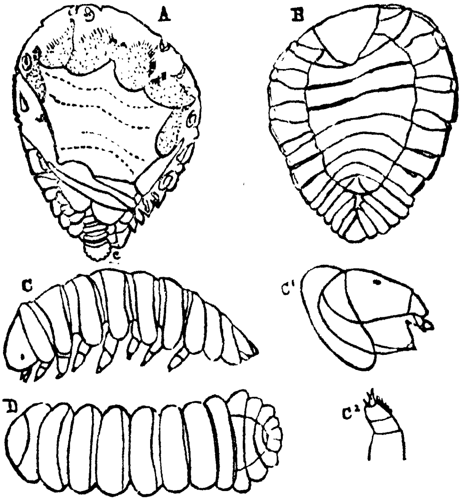

FIG. 262.

FIG. 260.—Section of the embryo pill-bug. *d*, intestine; *l*, epithelium forming the walls of the two lobes of the liver; *g*, transverse section of the nervous cord: *h*, walls of the body.—After Bobretzky.

FIG. 261.—Section of more advanced embryo pill-bug. *h*, heart; *hp*, hypodermal layer or body-walls; *m*, muscular wall of the intestine; *e*, epithelial lining of the intestine; *p*, dividing cell-wall between the heart and intestine; *l*, two lobes of the liver; *g*, ganglion. the clear space being filled with the fine granular substance of the ganglion.—After Bobretzky.

FIG. 262.—*Bopyrus*. *A*, ventral, *B*, dorsal side of the female; *C*, lateral and *D*, dorsal view of the male; c^1, head and first thoracic segment; c^2, antennæ—all enlarged.—Packard, del.

the sharp hook-like legs around the margin of the body. The head has no eyes nor appendages. The male (Fig. 262, *C*, *D*) is but slightly modified, is very minute, and is lodged partly out of sight under the ventral plates of the female, whose body is about five millimetres (a fifth of an inch) in length.

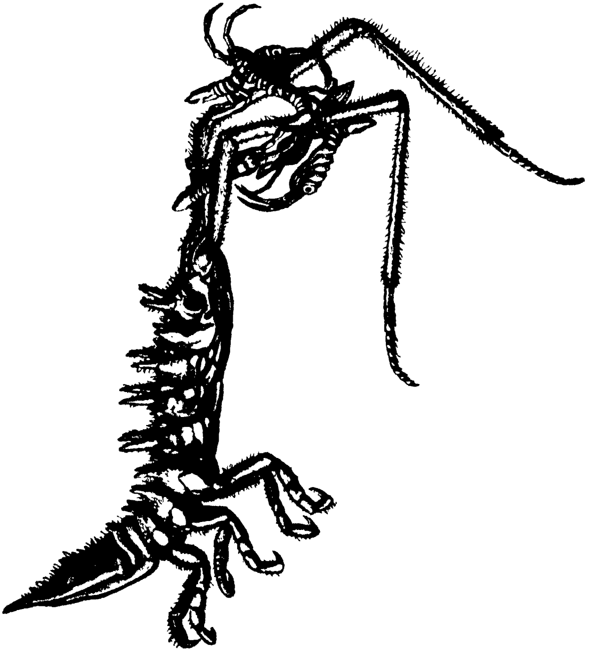

Fig. 263.—***Arcturus Baffini***, **with its young clinging to its antennæ.—After Wyville-Thompson.**

Various species of *Porcellio* (sow-bugs) live under stones on land; and allied to *Asellus*, the water sow-bug, is the marine *Limnoria lignorum* White, which is very injurious to the piles of bridges, wharves, and any submerged wood. The highest Isopods are *Idotæa*, of which *I. irroratus* Say (Fig. 255) is our most abundant species, being common in eel-grass, etc., between and just below tide-marks; and *Arcturus* (Fig. 263, *A. Baffini* Sabine), from the Arctic seas.

The series of Amphipods begins with *Cyamus ceti* (Linn.), the whale-louse, passes into *Caprella,* with its linear body and spider-like legs, to *Hyperia,* which lives as a mess-mate of the jelly-fish, *Cyanea,* and culminates in the water-flea (*Gammarus ornatus* Edwards) and sand-flea (*Orchestia agilis* Smith), abundant and leaping in all directions from under dried sea-weed at high-water mark.

Fig. 264 represents *Gammarus robustus* Smith, a fresh-water form common in the western territories.

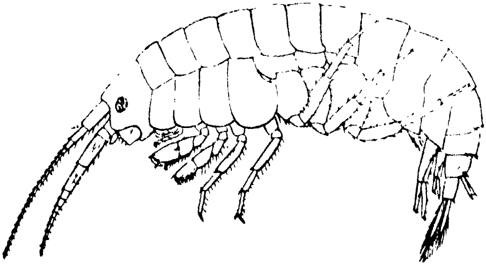

Fig. 264.—*Gammarus robustus* Smith. Utah. Enlarged.—After Smith.

Order 5. *Phyllocarida.*—This name is proposed for a group of Crustacea, the forerunner of the Decapoda and hitherto regarded as simply a family (*Nebaliadæ*), in which there is an interesting combination of Copepod, Phyllopod, and Decapod characters, with others quite peculiar to themselves.* The type is an instance of a generalized one, and is very ancient, having been ushered in during the earliest Silurian period, when there were (for Crustacea) gigantic forms (*Dithyrocaris* was over one foot in length) compared with those living at the present day. The order connects the Decapods with the Phyllopods and lower orders. The modern *Nebalia* is small, about a centimetre (.40–.50 inch) in length, with the body compressed, four of the abdominal segments projecting beyond the carapace, the last abdominal segment bearing two large spines. There is a large rostrum overhanging the head; stalked eyes, and two pairs of antennæ, the second pair nearly as long as the body and many-jointed. The mandibles are succeeded by two pairs of maxillæ. Behind these mouth-parts are eight pairs of short, leaf-like respiratory feet, which do not project beyond the edge of the carapace. These are succeeded by four pairs of large, long swimming feet, and there are two additional pairs of small abdominal feet. There is no metamorphosis, development being direct, the young hatching in the form of the adult. Of the fossil forms, *Hymenocaris* was regarded by Salter as the more generalized type. The genera *Peltocaris* and *Discinocaris* characterize the Lower Silurian period; *Ceratiocaris* the upper; *Dictyocaris* the Upper Silurian and Lowest Devonian strata; *Dithyrocaris* and *Argus* the Carboniferous period. Our northeastern and arctic species is *Nebalia bipes* (Fabricius), which occurs from Maine to Greenland.

Order 6. Stomapoda. In the small group represented by *Squilla* the gills are attached to the base of the hinder abdominal feet. *Squilla* lives in holes below low-water mark.

Order 7. Decapoda (Shrimps, Lobsters, Crabs).—A general knowedge of the Crustacea representing this, the highest order of the class, may be obtained by a study of the craw-fish and lobster. All Decapods have twenty segments in the body, a carapace covering the thorax and concealing the gills, which are highly specialized and attached to the maxillipedes and to the legs; usually a pair of stalked eyes, two unequal pairs of antennæ, the hinder pair the larger and longer; a pair of mandibles, often provided with a palpus, two pairs of lobed maxillæ, three pairs of maxillipedes, while the name of the order is derived from the fact that there are five pairs of well-marked legs, or ten in all. To the abdomen are appended six pairs of swimming feet. called "swimmerets." Another distinctive characteristic of most, in fact all the higher Decapods, is the short, or five or six-sided heart.

The early phases of embryological development in the Decapods are much as in the Tetradecapods. Most Decapods leave the egg in a larval state called the *Zoëa.* Certain Zoëæ having originally been supposed to have been adult Crustaceans, were described under the name *Zoëa.* In this condition there are no thoracic feet, and usually at first no abdominal feet; the compound eyes are large and usually sessile, and the carapace is often armed with a long dorsal and frontal spine. Fig. 265 represents the Zoëa, or larva of the common shore crab (*Cancer irroratus* Say). After several moults, the thoracic legs appear, the mouth-parts change from swimming-legs to appendages fitted for preparing the food to be swallowed and digested. This stage in the short-tailed Decapods or crabs, is called the *Megalops* stage (Fig. 266); certain immature crabs having been mistaken for and described as mature Crustacea, under the name Megalops. After swimming about the surface in the *Zoëa* and *Megalops* conditions, the body becomes more bulky, more concentrated headwards, and the crab descends to the bottom and hides under stones, etc.

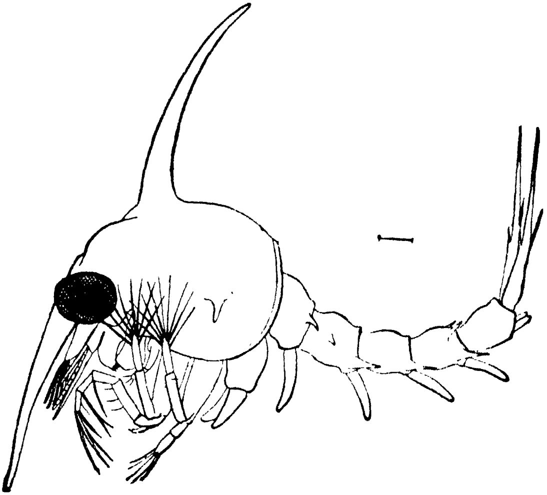

Fig. 265.—Zoëa of the common Crab. Cancer. Much enlarged.—After Smith.

The development of the individual crab is, in a general sense, an epitome of the development of the order. In the lowest Decapods, as in *Cuma* and *Mysis*, the form is somewhat like an advanced Zoëa, while the remarkable concentration of the parts headwards, seen in the crabs, is a great step upwards. Dana's law of cephalization, or transfer of parts headwards, is more strikingly manifested in the Crustacea than in any other animals.

Nearly all Decapods undergo this decided metamorphosis; in only a few forms, such as the craw-fish, lobster, and a few shrimps and crabs, do the young leave the egg in the general form of the adult, the Zoëa stage being rapidly assumed and discarded during embryonic life. Most Crustacea bear their eggs about with them; in only a few cases, as the *Squilla* and the land-crab of the West Indies, are the eggs left by the parent in holes or on the sea-shore.

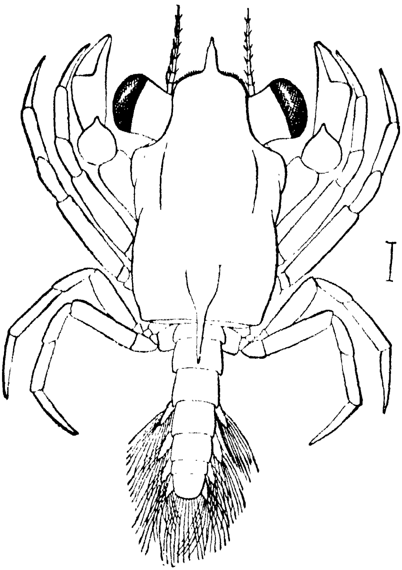

Fig. 266.—Megalops of the Crab.—After Smith.

The Decapoda are divided into the *Schizopoda*, represented by *Mysis*; the *Cumacea*, represented by *Cuma*; the long-tailed Decapods, such as the shrimps and lobster, called *Macrura*, and the genuine short-tailed Decapoda, or *Brachyura*. Most of the species of the crabs are confined to tropical seas and live in shallow water.

The Decapods appeared in the Coal Period, and were represented by somewhat generalized forms, such as *Anthrapalæmon* (Fig. 267) from the coal measures of Illinois. Recently a genuine crab (*Brachypyge carbonis*) has been described by Woodward from the carboniferous formation of Belgium.

Crustacea, especially shrimps and crabs, are sensitive to shocks and sounds. When alarmed, lobsters are said to cast off their large claws, but the latter are again renewed. It is more probable, however, that the claws are torn off during their contests with each other. Hensen found that crabs and shrimps living in water do not notice sounds made in the air. The hairs about the mouth are the organs of tactile sense, and have been made by Hensen to vibrate to certain sounds. The eyes may be greatly developed in shrimps living at great depths; thus *Thalascaris*, a shrimp living near the bottom of the Atlantic Ocean, is remarkable for the large size of its eyes. In the species of *Alpheus*, which live in holes in sponges, etc., the eyes are small. The eyes of the blind *Willemœsia*, dredged at great depths by the "Challenger" Expedition, are rudimentary, though in the young the eyes are better developed. This is the case with the young of the blind craw-fish *Cambarus pellucidus* (Tellkampf, Fig, 268) of Mammoth and other caves. The fact that the eyes in the young are larger than in the adult indicates that this species has descended from other forms living in neighboring streams, and well endowed with the sense of sight. The eye (Fig. 269) of the blind craw-fish differs from that of the normal species in its smaller size, conical form, the absence of a cornea (indicated by the dotted lines in *A*), the pigment cells being white instead of black, and by differences in the form of the brain, that of the blind species being fuller on the sides, and wanting the conical projection in front.

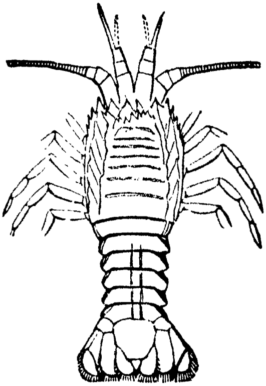
Fig. 267.—*Anthrapalæmon gracilis*. Natural size.—After Meek and Worthen.

Subclass 2. *Palæocarida.*—This subclass is proposed for the king-crab (*Limulus*), the only survivor of a large number of fossil Crustacea, which dominated the Silurian seas and became mostly extinct in the Carboniferous period.

It comprises the order of *Merostomata* represented at the present day by the king-crab, and the order *Trilobita,* which is wholly extinct. The organization of the king-crab is so wholly unlike that of other Crustacea, when we consider the want of antennæ, the fact that the nervous system is

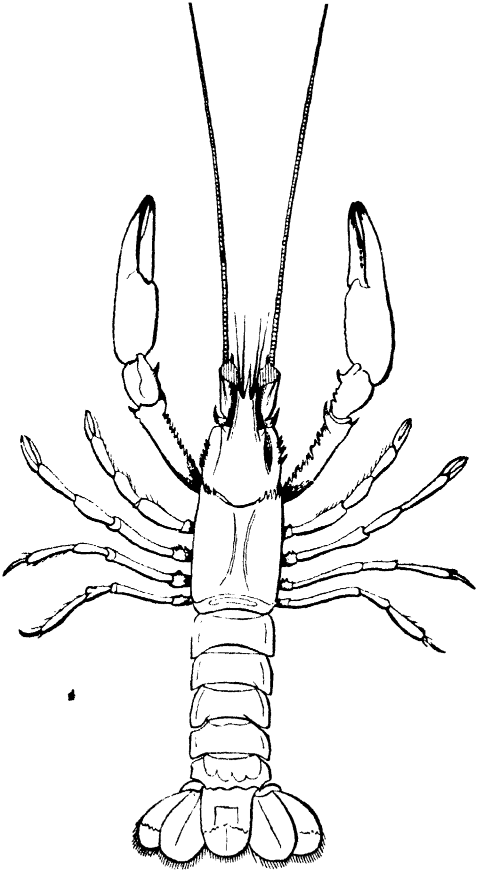

Fig. 268.—*Cambarus pellucidus*, the blind craw-fish of Mammoth Cave. Natural size.

peculiar in form and also ensheathed by arteries, and the peculiar nature of the gills of the abdominal feet, as well as the highly developed system of blood-vessels; that we are obliged to place them in a subclass equivalent to all the other Crustacea. It is possible that future research may prove that the *Palæocarida* should form a distinct class of Arthropods, equivalent on the one hand to the *Crustacea* and on the other to the *Insecta*, but from the fact that they breathe like other Crustacea by external gills, we prefer to retain them as a subdivision of the class of Crustacea.

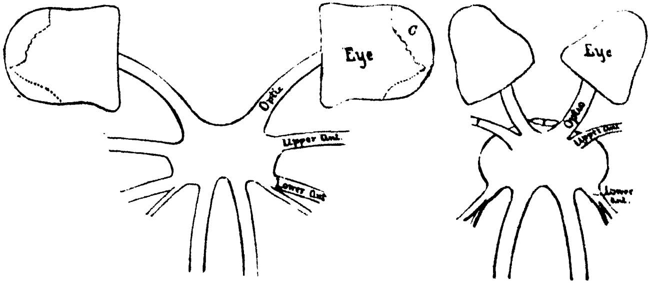

Fig. 269.—*A*, Brain and eye of a normal Cambarus from Iowa. *B*, The same of the blind craw-fish from Mammoth Cave. *C*, Cornea.—Packard, del.

Order 1. *Merostomata.*—The only living representative of this order is the king-crab, belonging to the genus *Limulus*, represented in American waters by *Limulus Polyphemus* Linn., which ranges from Casco Bay, Maine, to Florida and the West Indies.

The body of the king-crab is very large, sometimes nearly two feet in length; it consists of a cephalo-thorax composed of six segments and an abdomen with nine segments, the ninth (telson) forming a long spine. The cephalo-thorax is broader than long, in shape somewhat like that of *Apus*, with a broad flat triangular fold on the under side. Above are two large lunate compound eyes, near the middle of the head, but quite remote from each other, and two small compound eyes situated close together near the front edge of the head. There are no antennæ, and the six pairs of appendages are of uniform shape like legs, not like mandibles or maxillæ, and are adapted for walking; the feet are provided with sharp teeth on the basal joint for retaining the food. The mouth is situated between the second pair; the first pair of legs are smaller than the others. All end in two simple claws, except the sixth pair, which are armed with several spatulate appendages serving to prop the creature as it burrows into the mud. The males differ from the females in the hand and opposing thumb of the second pair of feet. These cephalo-thoracic appendages are quite as different from those of other Crustacea as those of the mites and spiders, which have a pair of mandibles and maxillæ, the latter provided with a palpus. Appended to the abdomen are six pairs of broad swimming feet, of which the second pair bear on the under side a set of about one hundred respiratory leaves or plates, into which the blood is sent from the heart, passing around the outer edge and returning around the inner edge. This mode of respiration is like that of the Isopods.

The alimentary canal consists of an œsophagus, which rises directly over the mouth, a stomach lined with rows of large chitinous teeth, with a large conical, stopper-like valve projecting into the posterior end of the body; the intestine is straight, ending in the base of the abdominal spine. The liver is very voluminous, ramifying throughout the cephalothorax. The nervous system is quite unlike that of other Crustacea; the brain is situated on the floor of the body in the same plane as the rest of the system, and sends a pair of nerves to the compound eyes, a single nerve supplying the ocelli.* The feet are all supplied with nerves from a thick ring surrounding the œsophagus. The nerves to the six pairs of abdominal legs are sent off from the ventral cord.

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* The nervous system of Limulus is quite unlike that of the Scorpion, where the brain is situated in the upper part of the head and supplies the maxillæ with nerves, and is situated directly over the infraœsophageal ganglion; and, besides, there is no œsophageal ring as in *Limulus*, only the two commissures connecting the brain with the infraœsophageal ganglion as usual in the Neocarida and Arachnida in general.

The heart is tubular, with eight pairs of valvular openings for the return of the venous blood which flows into the pericardial sac from all parts of the body; the arterial blood

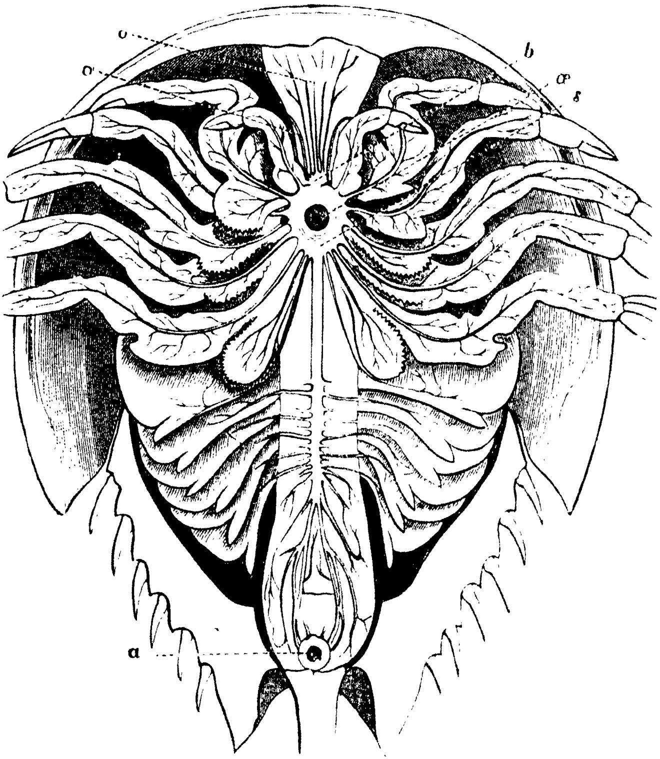


Fig. 270.—Nervous and part of the circulatory system of *Limulus polyphemus*, the King-Crab. *a*, vent; *œ*, œsophagus; *b*, brain; *o*, nerve to the smaller eyes; *o'*, nerve to the larger eyes; *s*, nerve-ring around the œsophagus. All the nerves are surrounded by an arterial coat.—After Milne Edwards.

is sent out from the arteries branching from the front end of the heart flowing around the upper side of the edge of the cephalo-thorax through numerous minute vessels. Also there are a pair of branchial arteries, and two arteries in the base of the spine.

The arrangement of the ventral system of arteries is very peculiar and quite characteristic of this animal. The œsophageal nervous ring, and in fact the entire nervous cord, is ensheathed in a vascular coat, so that the nervous system and its branches are bathed by arterial blood. The veins are better developed than usual; there being in the cephalo-thorax two large collective veins along each side of the intestine.

Closely connected with the two large collective veins are two large yellowish glandular bodies each with four branches extending up into the dorsal side of the cephalo-thorax. They are probably renal in their nature.

Both the ovaries and testes are voluminous glands, each opening by two papillæ on the under side of the first abdominal feet. At the time of spawning the ovary is greatly distended, the branches filled with green eggs.

Unlike most Crustacea, the female king-crab buries her eggs in the sand between tide-marks, and there leaves them at the mercy of the waves, until the young hatch. The eggs are laid in the Northern States between the end of May and early in July, and the young are from a month to six weeks in hatching.

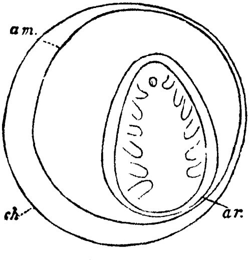


FIG. 271.

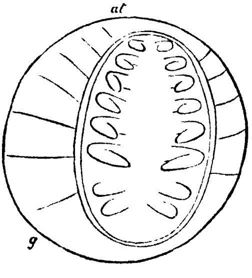


FIG. 272.

Fig. 271.—Embryo of King-crab, enlarged; *am*, serous membrane; *ch*, chorion.
Fig. 272.—The same, more advanced.

After fertilization the yolk undergoes total segmentation, much as in spiders and the craw-fish. When the primitive disk is formed the outer layer of blastodermic cells peels off soon after the limbs begin to appear, and this constitutes the serous membrane (Fig. 271, *am*), which is like that of insects.

Then the limbs bud out; the six pairs of cephalic limbs appear at once as in Fig. 271. Soon after the two basal pairs of abdominal leaf-like feet arise, the abdomen becomes separated from the front region of the body, and the segments are indicated as in Fig. 272. A later stage (Fig. 273) is signalized by the more highly developed dorsal portion of the embryo, an increase in size of the abdomen, and the appearance of nine distinct abdominal segments. The segments of the cephalo-thorax are now very clearly defined, as also the division between the cephalo-thorax and abdomen, the latter being now nearly as broad as the cephalo-thorax, the sides of which are not spread out as in a later stage.

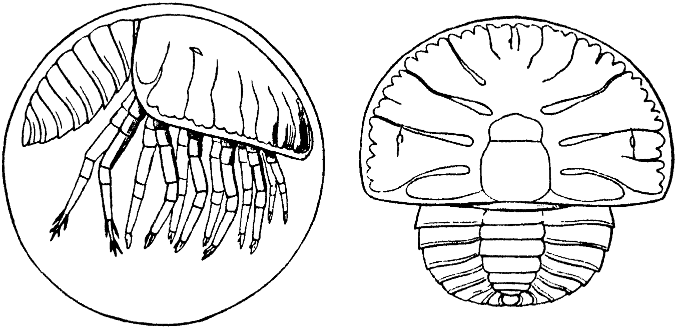


Fig. 273.—King-crab shortly before hatching; trilobitic stage, enlarged; side and dorsal view.

At this stage the egg-shell has split asunder and dropped off, while the serous membrane, acting as a vicarious egg-shell, has increased in size to an unusual extent, several times exceeding its original dimensions and filled with sea-water, in which the embryo revolves.

At a little later period the embryo throws off an embryonal skin (amnion), the thin pellicle floating about in the egg. Still later in the life of the embryo the claws are developed, an additional rudimentary gill appears, and the abdomen grows broader and larger, with the segments more distinct; the heart also appears, being a pale streak along the middle of the back extending from the front edge of the head to the base of the abdomen.

Just before hatching the head-region spreads out, the abdomen being a little more than half as wide as the cephalothorax. The two compound eyes and the pair of ocelli on the front edge of the head are quite distinct; the appendages to the gills appear on the two anterior pairs, and the legs are longer.

The resemblance to a Trilobite is most remarkable, as seen in Fig. 273. It now also closely resembles the fossil king-crabs of the Carboniferous formation (Fig. 274, *Prestwichia rotundatus*, Fig. 275, *Euproöps Danæ*).

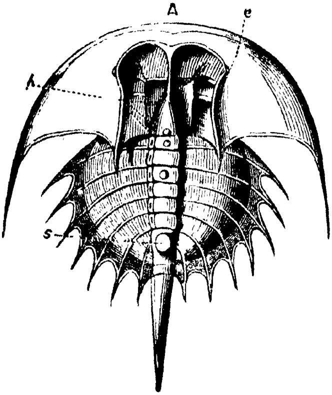


Fig. 274.—Prestwichia, natural size.—After Worthen.

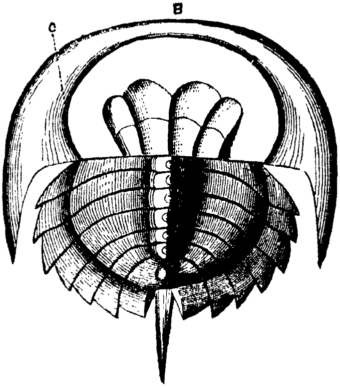


Fig. 275.—Euproöps, natural size.—After Worthen.

In about six weeks from the time the eggs are laid the embryo hatches. It now differs chiefly from the previous stage in the abdomen being much larger, scarcely less in size than the cephalo-thorax; in the obliteration of the segments, except where they are faintly indicated on the cardiac region of the abdomen, while the gills are much larger than before. The abdominal spine is very rudimentary; it forms the ninth abdominal segment.

The reader may now compare with our figures of the recently hatched Limulus (Fig. 276), that of Barrande's larva of *Trinucleus ornatus* (Fig. 277, natural size and enlarged). He will see at a glance that the young Trilobite, born without any true thoracic segments, and with the head articulated with the abdomen, closely resembles the young Limulus. In Limulus no new segments are added after birth; in the Trilobites the numerous thoracic segments are added during successive moults. The Trilobites thus pass through a well-marked metamorphosis, though by no means so remarkable as that of the Decapods and the Phyllopods.

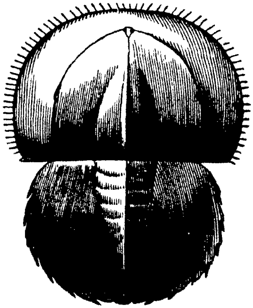


Fig. 276. – Larva of the King-crab.

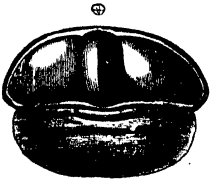


Fig. 277.—Larva of a Trilobite, *Trinucleus ornatus*.—After Barrande.

The young king-crabs swim briskly up and down, skimming about on their backs like Phyllopods, by flapping their gills, not bending their bodies. In a succeeding moult, which occurs between three and four weeks after hatching, the abdomen becomes smaller in proportion to the head, and the abdominal spine is about three times as long as broad. At this and also in the second, or succeeding moult, which occurs about four weeks after the first moult, the young king-crab doubles in size. It is probable that specimens an inch long are about a year old, and it must require several years for them to attain a length of one foot.

The *Limuli* of the Solenhofen slates (Jurassic) scarcely differed in appearance from those of their living descendants.

Limulus, Prestwichia, Bellinurus, and *Euproöps* form the representatives of the suborder *Xiphosura.* The second suborder *Eurypterida* is represented by extinct genera *Pterygotus, Eurypterus* and allies which appeared in the upper Silurian Period and became extinct in the Coal Period. In these forms the cephalothorax is small, flattened and nearly square, while the abdomen is long, with twelve or thirteen segments, the last one forming a spoon-shaped or acute spine. The appendages of the cephalothorax were adapted for walking, one pair sometimes large and chelate; the hinder pair paddle-like. The gills were arranged like the teeth in a rake, the flat faces being fore and aft. While the king-crab burrows in the mud and lives on sea-worms, the *Eurypterida* probably swam near the surface, and were more predatory than the king-crabs. The *Merostomata* are a generalized type, with some resemblances to the *Arachnida* as well as to the genuine Crustacea, representing the larval or Zoëa form of the Decapods.

Order 2. *Trilobita.*—The members of this group are all extinct. The body has a thick dense integument like that of *Limulus*, and is often variously ornamented with tubercles and spines. The body is divided into three longitudinal lobes, the central situated over the region of the heart as in *Limulus.* The body is more specialized than in the *Merostomata*, being divided into a true head consisting of six segments bearing jointed appendages, somewhat like those of the *Merostomata,* with from two to twenty-six distinct thoracic segments (probably bearing short jointed limbs not extending beyond the edge of the body, which supported swimming and respiratory lobes). The abdomen consisted of several (greatest number twenty-eight) coalesced segments, forming a solid portion (*pygidium*), sometimes ending in a spine, and probably bearing membranous swimming feet. The larval trilobite was like that of a king-crab, and after a number of moults acquired its thoracic segments, there being a well-marked metamorphosis. The Trilobites (*Paradoxides, Agnostus,* etc.) appeared in the lowest Silurian strata, culminated in the upper Silurian, and died out at the close of the Coal Period.

CLASS. I. CRUSTACEA.

Arthropoda breathing by gills situated on the legs, or respiring through the body-walls. Body in the higher forms divided into two regions, a cephalo-thorax and abdomen. Two pairs of antennæ; mandibles usually with a palpus. Heart nearly square, or in the lower forms tubular. Often a distinct metamorphosis. Sexes distinct, except in a few cases (certain barnacles, etc.).

Subclass 1. *Neocarida.*—Genuine Crustacea, with two pairs of antennæ; biting mouth-parts; mostly modern types.

Order 1. *Cirripedia.*—Sessile often retrograded; antennæ not developed, living parasitically, the appendages of the head sometimes forming net-like organs. Young hatched in the nauplius state. Suborder 1.—*Rhizocephala* (Sacculina, Peltogaster). Suborder 2.—Genuine Cirripedia (Balanus, Lepas.)

Order 2. *Entomostraca.*—A cephalo-thorax developed; mandibles and three pairs of maxillæ; five pairs of thoracic feet, no abdominal feet; without any gills. The parasitic forms more or less modified in shape, with sucking mouth-parts; all the young of the nauplius form. Suborder 1. *Copepoda* (Cyclops). Suborder 2. *Siphonostoma* (Lernæa, Caligus, and Argulus).

Order 3. *Branchiopoda.* Thoracic feet leaf-like; one to three pairs of maxillæ; number of body-segments varying from a few to sixty; cephalo-thorax often well developed, and forming a bivalved shell. Young usually a Nauplius. Suborder 1. *Ostracoda* (Cypris). Suborder 2. *Cladocera* (Daphnia). Suborder 3. *Phyllopoda* (Limnadia, Apus, Branchipus, and Artemia.)

Order 4. *Phyllocarida.*—Body compressed; rostrum distinct from the carapace; thoracic feet leaf-like; no metamorphosis. (Nebalia.)

Order 5.—*Tetradecapoda.*—No cephalo-thorax, thoracic segments distinct; respiration often carried on by the abdominal feet. Suborder 1. *Isopoda* (Idotæa, Asellus). Suborder 2. *Amphipoda* (Gammarus).

Order 6. *Stomapoda.*—Abdominal feet respiratory. (Squilla.)

Order 7. *Decapoda.*—Cephalo-thorax well marked, abdomen often bent beneath the cephalo-thorax; breathing by gills attached to the maxillipedes and legs. Heart often nearly square. Usually a well-marked metamorphosis; young called a

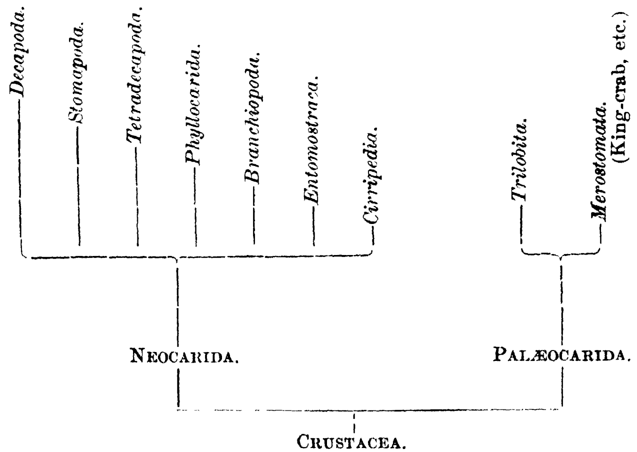
Zoëa. Suborder 1. *Cumacea* (Cuma). Suborder 2. *Schizopoda* (Mysis). Suborder 3. *Macrura* (Crangon, Astacus, Homarus). Suborder 4. *Brachyura* (Cancer).

Subclass 2. *Palæocarida.*—Appendages of the cephalo-thorax in the form of legs, rather than jaws; no antennæ; brain supplying nerves to the eyes alone; nerves to the cephalo-thoracic appendages sent off from an œsophageal ring; nervous system ensheathed by a ventral system of arteries; metamorphosis slight. Sexes distinct.

Order 1. *Merostomata.*—No distinct thoracic segments and appendages. (Limulus, Eurypterus.)

Order 2. *Trilobita.*—Numerous free thoracic segments and jointed appendages. (Agnostus, Paradoxides, Calymene, Trinucleus, Asaphus; all extinct.)

CLASSIFICATION OF THE SUBCLASSES AND ORDERS OF CRUSTACEA.



Laboratory Work.—In dissecting the lobster, the shell or crust may be removed by a stout knife; the whole dorsal portion of the cephalo-thorax and each segment behind, including the base of the telson, should be removed, care being taken not to injure the brain, which lies just under the base of the rostrum. The hypodermis, or reddish, membranous, inner layer of the integument, should then be dissected away, exposing the heart, the stomach, the liver, and the large muscles of the abdomen. The arterial system can be injected with carmine through the heart, and the finer arteries traced into the large claws and legs. In the crab, the entire upper side of the carapace may be removed by the point of a knife. The smaller Crustacea, especially the water-fleas, may be examined alive under the microscope as transparent objects. In the larger forms the stomach may be laid open by the scissors in order to study its complicated structure. The eyes of the lobster should be hardened in alcohol and fine sections made for the microscope. This is an operation requiring much care and experience. Experts in embryology have sliced the eggs of certain Crustacea and studied their embryology with great success.

CLASS II.—INSECTA (*Centipedes, Mites, Spiders, Winged Insects*).

General Characters of Insects.—While in the worms there is no grouping of the segments into regions, we have seen that in most *Crustacea* there are two assemblages of segments—*i. e.*, a head-thorax and abdomen. In the insects there is a step higher in the scale of life, a head is separated from the rest of the body, which is divided into three regions, the head, thorax, and hind-body (abdomen). Moreover, the insects differ from the *Crustacea* in breathing by internal air-tubes which open through breathing-holes (spiracles) in the sides of the body. The six-footed insects also have wings, and their presence is correlated with a differentiation or subdivision of the two hinder segments of the thorax into numerous pieces.

The number of body-segments in winged insects is seventeen or eighteen—*i. e.*, four in the head, three in the thorax, and ten or eleven in the hind-body. In spiders and mites there are usually but two segments in the head, four in the thorax, and a varying number (not more than twelve) in the abdomen ; in Myriopods the number of segments varies greatly—*i. e.*, from ten to two hundred. The appendages of the body are jointed, and perform four different functions—*i. e.*, the antennæ are sensorial organs, the jaws and maxillæ are for seizing and chewing or sucking food ; the thoracic appendages are for walking, and the spinnerets of the spider, as well as the sting or ovipositor of many insects, are subservient in part to the continuance of the species.

Of the winged insects there are two types: first, those in which the jaws and maxillæ are free, adapted for biting, as in the locust or grasshopper, and, second, those in which the jaws and maxillæ are more or less modified to suck or lap up liquid food, as in the butterfly, bee, and bug.

Nearly all insects undergo a metamorphosis, the young being called a *larva* (caterpillar, grub, maggot); the larva transforms into a *pupa* (chrysalis), and the pupa into the adult (imago).

In order to obtain a knowledge of the structure, external and internal, of insects, the student should make a careful study of the anatomy of a locust or grasshopper with the aid of the following description; and afterward rear from the egg a caterpillar and watch the different steps in its metamorphosis into a pupa and adult. The knowledge thus acquired will be worth more to the student than a volume of descriptions.

On making a superficial examination of the locust (*Caloptenus femur-rubrum*, or *C. spretus*), its body will be seen to consist of an external crust, or thick, hard integument, protecting the soft parts or viscera within. This integument is at intervals segmented or jointed, the segments more or less like rings, which, in turn, are subdivided into pieces. These segments are most simple and easily comprehended in the abdomen or hind-body, which is composed of ten of them. The body consists of seventeen of these segments, variously modified and more or less imperfect and difficult to make out, especially at each extremity of the body—*i.e.*, in the head and at the end of the abdomen. These seventeen segments, moreover, are grouped into three regions, four composing the head, three the thorax, and ten the hind-body, or abdomen. On examining the abdomen, it will be found that the rings are quite perfect, and that each segment may be divided into an upper (tergal), a lateral (pleural), and an under (sternal) portion, or arc (Fig. 278, *A*).

These parts are respectively called *tergite*, *pleurite*, and *sternite*, while the upper region of the body is called the

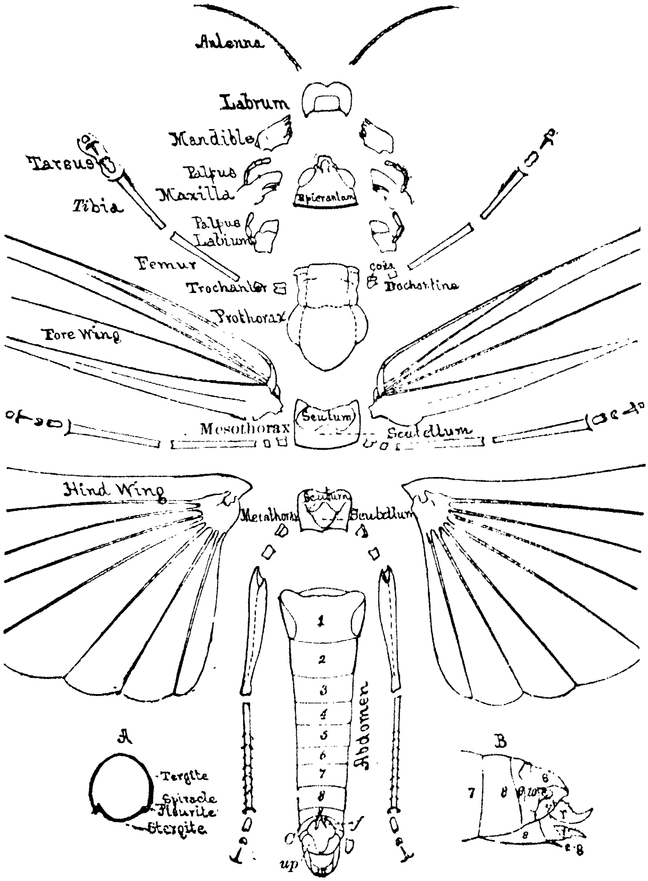


Fig. 278.—External anatomy of *Caloptenus spretus*, the head and thorax disjointed. *up*, uropatagium; *f*, furcula: *c*, cercus.—Drawn by J. S. Kingsley.

tergum, the lateral the *pleurum*, and the ventral or under portion the *sternum*.

As these parts are less complicated in the abdomen, we will first study this region of the body, and then examine the more complex thorax and head. The abdomen is a little over half as long as the body, the tergum extending far down on the side and merging into the pleurum without any suture or seam. The pleurum is indicated by the row of spiracles, which will be noticed further on. The sternum forms the ventral side of the abdomen, and meets the pleurum on the side of the body.

In the female (Fig. 278, *B*), the abdomen tapers somewhat toward the end of the body, to which are appended the two pairs of stout, hooked spines, forming the ovipositor (Fig. 278, *B*, *r*, *r'*). The anus is situated above the upper and larger pair, and the external opening of the oviduct, which is situated between the smaller and lower pair of spines, and is bounded on the ventral side by a movable triangular acute flap, the egg-guide (Fig. 278, *B*, *eg*, and Fig. 281).

The thorax, as seen in Fig. 278, consists of three segments, called the prothorax, mesothorax, and metathorax, or fore, middle, and hind thoracic rings. They each bear a pair of legs, and the two hinder each a pair of wings. The upper portion (tergum) of the middle and hind segments, owing to the presence of wings and the necessity of freedom of movement to the muscles of flight, are divided or differentiated into two pieces, the *scutum* and *scutellum** (Fig. 278), the former the larger, extending across the back, and the scutellum a smaller, central, shield-like piece. The protergum, or what is usually in the books called the prothorax, represents either the scutum or both scutum and scutellum, the two not being differentiated.

The fore wings are long and narrow, and thicker than the hinder, which are broad, thin, and membranous, and most active in flight, being folded up like a fan when at rest and tucked away out of sight under the fore wings, which act as wing-covers.

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* There are in many insects, as in many *Lepidoptera* and *Hymenoptera* and some *Neuroptera*, four tergal pieces—*i. e.*, præscutum, scutum, scutellum, and postscutellum, the first and fourth pieces being usually very small and often obsolete.

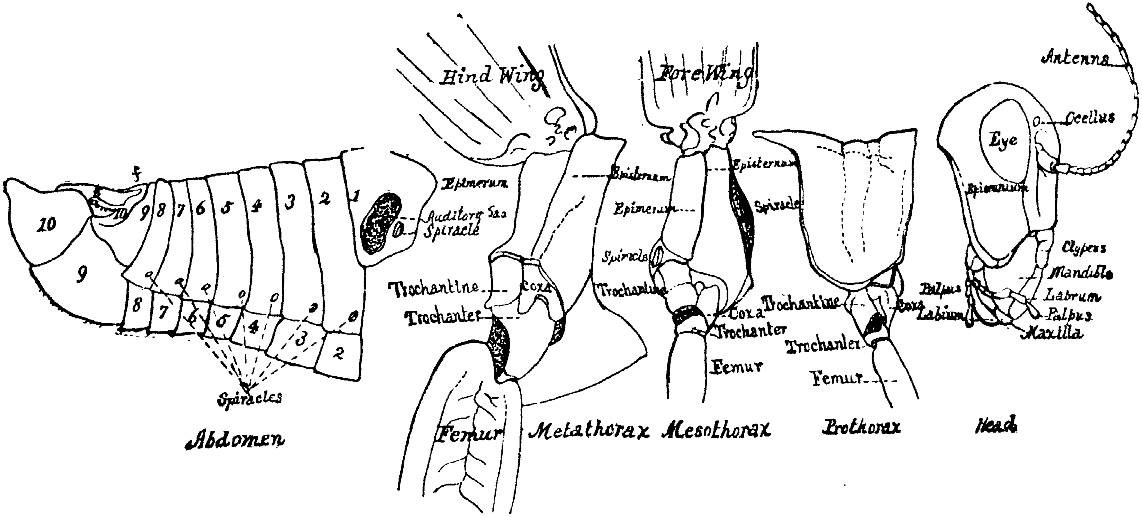


Fig. 279.—Male *Caloptenus spretus*.—Dissected and drawn by J. S. Kingsley.

Turning now to the side of the body under the insertion of the wing (Fig. 279), we see that the side of each of the middle and hind thoracic rings is composed of two pieces, the anterior, *episternum*, resting on the sternum, with the *epimerum* behind it; these pieces are vertically high and narrow, and to them the leg is inserted by three pieces, called respectively *coxa*, *trochantine*, and *trochanter* (see Fig. 279), the latter forming a true joint of the leg.

The legs consist of five well-marked joints, the *femur* (thigh), *tibia* (shank), and *tarsus* (foot), the latter consisting in the locust of three joints, the third bearing two large claws with a pad between them. The hind legs, especially the femur and tibia, are very large, adapted for hopping.

The sternum is broad and large in the middle and hind thorax, but small and obscurely limited in the prothorax, with a large conical projection between the legs.

The head is mainly in the adult locust composed of a single piece called the *epicranium* (Figs. 279 and 280, *E*), which carries the compound eyes, ocelli, or simple eyes (Fig. 280, *e*), and antennæ. While there are in reality four primary segments in the head of all winged insects, corresponding to the four pairs of appendages in the head, the posterior three segments, after early embryonic life in the locust, become obsolete, and are mainly represented by their appendages and by small portions to which the appendages are attached. The epicranium represents the antennal segment, and mostly corresponds to the tergum of the segment. The antennæ, or feelers, are inserted in front of the eyes, and between them is the anterior ocellus, or simple eye, while the two posterior ocelli are situated above the insertion of the antennæ. In front of the epicranium is the *clypeus* (Fig. 280), a piece nearly twice as broad as long. To the clypeus is attached a loose flap, which covers the jaws when they are at rest. This is the upper lip or *labrum* (Fig. 280).

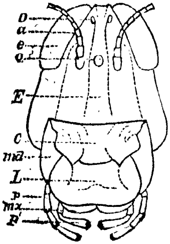


Fig. 280.—Front view of the head of *C. spretus*. *E*, epicranium; *C*, clypeus; *L*, labrum; *o o*, ocelli; *e*, eye; *a*, antenna; *md*, mandible; *mx*, portion of maxilla uncovered by the labrum; *p*, maxillary palpus; *p'*, labial palpus.—Kingsley *del.*

There are three pairs of mouth-appendages: first, the true jaws or mandibles (Fig. 278), which are single-jointed, and are broad, short, solid, with a toothed cutting and grinding edge, adapted for biting. The mandibles are situated on each side of the mouth-opening. Behind the mandibles are the maxillæ (Fig. 278), which are divided into three lobes, the inner armed with teeth or spines, the middle lobe unarmed and spatula-shaped, while the outer forms a five-jointed feeler called the *maxillary palpus*. The maxillæ are accessory jaws, and probably serve to hold and arrange the food to be ground by the true jaws. The floor of the mouth is formed by the *labium* (Figs. 278 and 279), which in reality is composed of the two second maxillæ, soldered together in the middle, the two halves being drawn separately in Fig. 278.

Within the mouth, and situated upon the labium, is the tongue (*lingua*), which is a large, membranous, partly hollow expansion of the base of the labrum; it is somewhat pyriform, slightly keeled above, and covered with fine, stiff hairs, which, when magnified, are seen to be long, rough, chitinous spines, with one or two slight points or tubercles on the side. These stiff hairs probably serve to retain the food in the mouth, and are, apparently, of the same structure as the teeth in the crop. The base of the tongue is narrow, and extends back to near the pharynx (or entrance to the gullet), there being on the floor of the mouth, behind the tongue, two oblique slight ridges, covered with stiff, golden hairs, like those on the tongue.

The internal anatomy may be studied by removing the dorsal wall of the body and also by hardening the insect several days in alcohol and cutting it in two longitudinally by a sharp scalpel.

The *œsophagus* (Fig. 281, *œ*) is short and curved, continuous with the roof of the mouth. There are several longitudinal irregular folds on the inner surface. It terminates in the centre of the head, directly under the supra-œsophageal ganglion, the end being indicated by several small conical valves closing the passage, thus preventing the regurgitation of the food. The two salivary glands consist each of a bunch of follicles, emptying by a common duct into the floor of the mouth.

The œsophagus is succeeded by the crop (*ingluvies*). It dilates rapidly in the head, and again enlarges before passing out of the head, and at the point of first expansion or enlargement there begins a circular or oblique series of folds, armed with a single or two alternating rows of simple spine-like teeth. Just after the crop leaves the head, the rugæ or folds become longitudinal, the teeth arranged in rows, each row formed of groups of from three to six teeth, which point backward so as to push the food into the stomach. In alcoholic specimens the folds of the crop and œsophagus are deep blood-red, while the muscular portion is flesh-colored. It is in the crop that the "molasses" thrown out by the locust originates.

The *proventriculus* is very small in the locust, easily overlooked in dissection, while in the green grasshoppers it is large and armed with sharp teeth. A transverse section of the crop of the cricket shows that there are six large irregular teeth armed with spines and hairs (Fig. 282). It forms a neck or constriction between the crop and true stomach. It may be studied by laying the alimentary canal open with a pair of fine scissors, and is then seen to be armed with six flat folds, suddenly terminating posteriorly, where the true stomach (chyle-stomach, *ventriculus*) begins. The chyle-stomach is about one half as thick as the crop, when the latter is distended with food, and is of nearly the same diameter throughout, being much paler than the reddish crop, and of a flesh-color.

From the anterior end arise six large *gastric cœca,* which are dilatations of the true chyle-stomach, and probably serve to present a larger surface from which the chyle may escape into the body-cavity and mix with the blood, there being in insects no lacteal vessels or lymphatic system.

The stomach ends at the posterior edge of the fourth abdominal segment in a slight constriction, at which point (pyloric end) the urinary tubes (*vasa urinaria,* Fig. 281, *ur*) arise. These are arranged in ten groups of about fifteen tubes, so that there are about one hundred and fifty long, fine tubes in all.

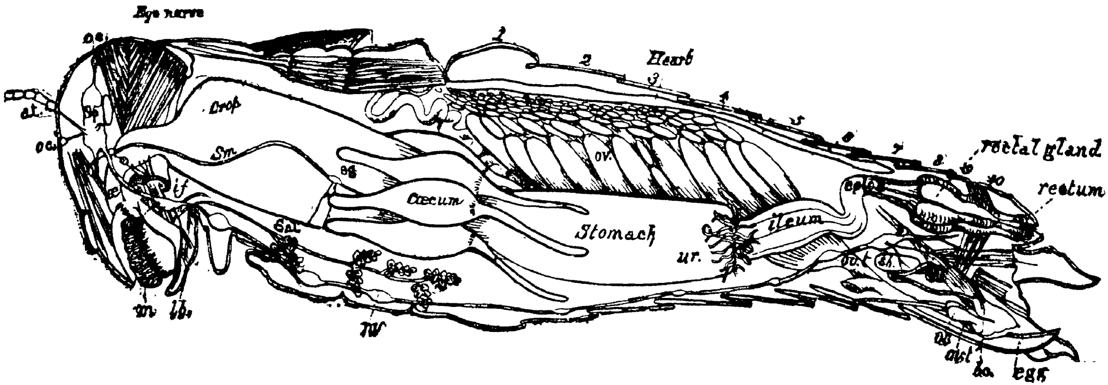


Fig. 281.—Internal anatomy of *Caloptenus femur-rubrum.* *at*, antenna and nerve leading to it from the "brain" or supra-œsophageal ganglion (*sp*); *oc*, ocelli, anterior and vertical ones, with ocellar nerves leading to them from the "brain;" œ, œsophagus; *m*, mouth: *lb*, labium or under lip; *if*, infra-œsophageal ganglion, sending three pairs of nerves to the mandibles, maxillæ, and labium respectively (not clearly shown in the engraving); *sm*, sympathetic or vagus nerve, starting from a ganglion resting above the œsophagus, and connecting with another ganglion (*sg*) near the hinder end of the crop; *sal*, salivary glands (the termination of the salivary duct not clearly shown by the engraver); *nv*, nervous cord and ganglia; *ov*, ovary; *ur*, urinary tubes (cut off, leaving the stumps); *ovt*, oviduct; *sb*, sebaceous gland; *bc*, bursa copulatrix; *ovt'*, site of opening of the oviduct (the left oviduct cut away); 1-10, abdominal segments. The other organs labelled in full.—Drawn from his original dissections by Mr. Edward Burgess.

The *intestine* (ileum) lies in the fifth and sixth abdominal segments.

Behind the intestine is the *colon*, which is smaller than the intestine proper, and makes a partial twist. The colon suddenly expands into the *rectum*, with six large *rectal glands* on the inside, held in place by six muscular bands attached anteriorly to the hinder end of the colon. The rectum turns up toward its end, and the vent is situated just below the supra-anal plate.

Having described the digestive canal of the locust, we may state in a summary way the functions of the different divisions of the tract. The food after being cut up by the jaws is acted upon while in the crop by the salivary fluid, which is alkaline, and possesses the property, as in vertebrates, of rapidly transforming the starchy elements of the food into soluble and assimilable glucose. The digestive action carried on in the crop (*ingluvies*) then, in a vegetable-feeding insect like the locust, results in the conversion of the starchy matters into glucose or sugar. This process goes on very slowly. When digestion in the crop has ended, the matters submitted to an energetic pressure by the walls of the crop, which make peristaltic contractions, filter gradually through the short, small proventriculus, directed by the furrows and chitinous projections lining it. The apparatus of teeth does not triturate the food, which has been sufficiently comminuted by the jaws. This is proved by the fact, says Plateau, that the parcels of food are of the same form and size as those in the crop, before passing through the proventriculus. The six large lateral pouches (cœca) emptying into the commencement of the stomach (ventriculus) are true glands, which secrete an al-

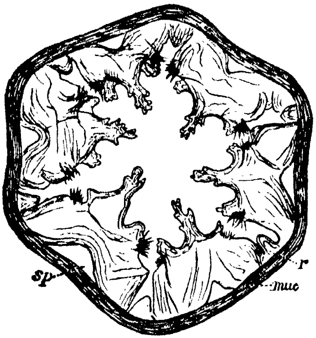


Fig 282.—Transverse section of the crop of *Gryllus cinereus* of Europe; *muc.* muscular walls; *r*, horny ridge between the large teeth.—After Minot.

kaline fluid, probably aiding in digestion. In the stomach (ventriculus) the portion of the food which has resisted the action of the crop is submitted to the action of a neutral or alkaline liquid, never acid, secreted by special local glands or by the lining epithelium. In the ileum and colon active absorption of the liquid portion of the food takes place, and the intestine proper (ileum and colon) is thus the seat of the secondary digestive phenomena. The reaction of the secretion is neutral or alkaline. The rectum is the stercoral reservoir. It may be empty or full of liquids, but never contains any gas. The liquid products secreted by the urinary tubes are here accumulated, and in certain circumstances here deposit the calculi or crystals of oxalic, uric, or phosphatic acid. Insects, says Plateau, have no special vessel to carry off the chyle, such as the lacteals or lymphatics of vertebrates; the products of digestion—viz., salts in solution, peptones, sugar in solution, and emulsionized greasy matters—pass through the fine coatings of the digestive canal by osmosis, and mingle outside of this canal with the currents of blood which pass along the ventral and lateral parts of the body.

Into the pyloric end of the stomach empty the urinary tubes, their secretions passing into the intestine. These are organs exclusively depuratory and urinary, relieving the body of the waste products. The liquid which they secrete contains urea (?), uric acid, and urates in abundance, hippuric acid (?), chloride of sodium, phosphates, carbonate of lime, oxalate of lime in quantity, leucine, and coloring matters.

The nervous system of the locust, as of other insects, consists of a series of nerve-centres, or so-called brains (ganglia), which are connected by two cords (commissures), the two cords in certain parts of the body in some insects united into one. There are in the locust ten ganglia, two in the head, three in the thorax, and five in the abdomen. The first ganglion is rather larger than the others, and is called the "brain." The brain rests upon the œsophagus, whence its name, supra-œsophageal ganglion. From the brain arise the large, short, optic nerves (Fig. 281, not lettered, but represented by the circle behind the brain, *sp*; Fig. 283, *op*), which go to the compound eyes, and from the front arise

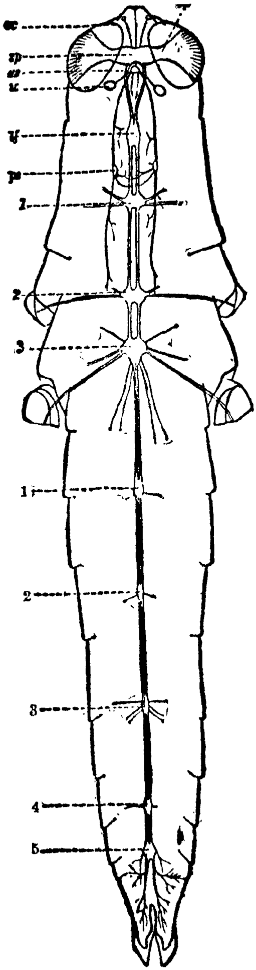


Fig. 283.—Nervous system of *Caloptenus spretus*. *sp*, supra-œsophageal ganglion, sending off the large optic nerve (*op*) to the eyes, and an ocellar nerve to each ocellus (the dotted line *oc* stops short of the left ocellus); *if*, infra-œsophageal ganglion; 1, 2, 3, thoracic ganglia; 1-5, five abdominal ganglia (the fifth the largest, and sending branches to the ovipositor, etc.). The sympathetic nerve and ganglia are represented by the two main nerves which arise from the medio-cephalic ganglion (*as*) resting on and above the œsophagus and two ganglia (*ps*) on the under side of the crop. From each of these ganglia two nerves are sent under the crop, and a larger nerve on each side to as far as the stomachal cæca, ending in the figure at the dotted line 2, near the second thoracic ganglion. *u*, a round, shining body, connected by a nerve with the medio-cephalic ganglion, its nature unknown. (Drawn by J. H. Emerton from dissections made by the author.)

the three slender filaments which are sent to the three ocelli (Fig. 281, *oc*). From immediately in front, low down, arise the antennal nerves (Fig. 281, *at*). The simple brain of the locust may be compared with the more complicated brain of an ant, as seen in Fig. 284.

The infra-œsophageal ganglion (Fig. 283, *if*), as its name implies, lies under the œsophagus at the base of the head, under a bridge of chitine, and directly behind the tongue. It is connected with the supra-œsophageal ganglion by two commissures passing up each side of the œsophagus. From the under side of the infra-œsophageal ganglion arise three pairs of nerves, which are distributed to the mandibles,

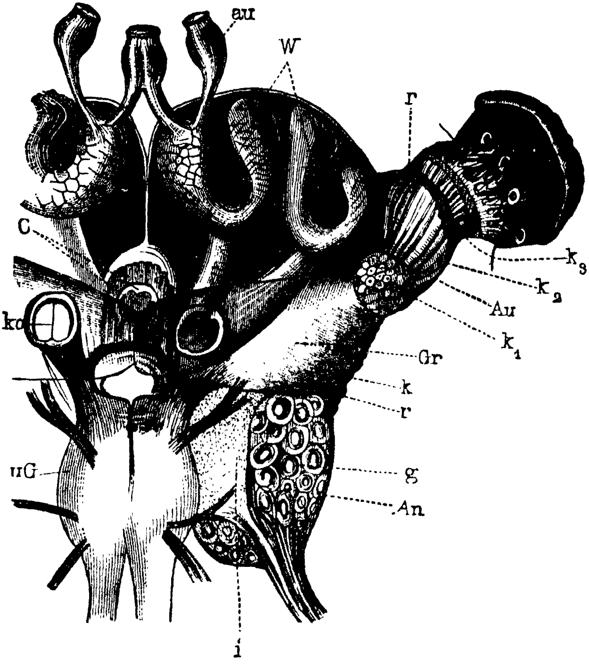


Fig. 284.—Right half of an ant's-brain; *uG*, infra-œsophageal ganglion; *Gr*, brain; *C*, central connective portions; *W*, semi-circular bodies of the small-celled portion of the brain lying next to the basal portion of the brain, from which the nerves to the simple eyes (*au*) arise; *Au*, optic lobes; *An*, antennal lobes (the bodies appearing like cells are rounded masses of the network of the substance of the cord; *r*, cellular cortical substance of the brain; *ko*, twofold body of the commissure connecting the brain with the infra-œsophageal ganglion.—After Leydig, from Graber.

maxillæ, and labium. The mandibular nerves project forward and arise from the anterior part of the ganglion, near the origin of the supra-œsophageal commissures, while the maxillary and labial nerves are directed downward into those organs.

The sympathetic ganglia are three in number; one situated just behind the supra-œsophageal ganglion (Fig. 278, *as*), resting on the œsophagus, and two others situated each side of the crop, low down. Each of the two posterior ganglia is supplied by a nerve from the anterior ganglion. Two nerves pass under the crop connecting the posterior ganglia, and from each posterior ganglion a nerve is sent backward to the end of the proventriculus. A pair of nerves pass under the œsophagus from each side of the anterior sympathetic ganglion, and another pair pass downward to a round white body, whose nature is unknown (Fig. 278, *u*).

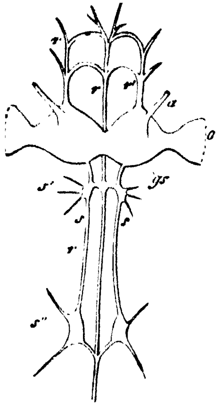


Fig. 280. — Supra-œsophageal ganglion and visceral (or sympathetic) nervous system of the silk-worm moth (*Bombyx mori*). *gs*, Supra-œsophageal ganglion ("brain"); *a*, antennary nerve; *o*, optic nerve; *r*, azygos trunk of the visceral nervous system; *r′*, its roots arising from the supra-œsophageal ganglion [illegible] onic enlargements *s′ s″*.—After Brandt, from Gegenbaur.

Fig. 280 represents an enlarged view of the brain and sympathetic nerve of a moth. The heart is a long tube lying in the abdomen, dilating at six places along its course, and ending in a conical point near the end of the abdomen; it is held in place by fine muscular bands.

All insects breathe by means of a complicated system of air-tubes ramifying throughout the body, the air entering through a row of spiracles, or air-holes, or breathing-holes (*stigmata*), in the sides of the body. There are in locusts two pairs of thoracic and eight pairs of abdominal spiracles. The first thoracic pair (Fig. 281) is situated on the membrane connecting the prothorax and mesothorax, and is covered by the hinder edge of the protergum (usually called prothorax). The second spiracle is situated on the posterior edge of the mesothorax. There are eight abdominal spiracles, the first one situated just in front of the auditory sac or tympanum (see Fig. 279), and the remaining seven are small openings along the side of the abdomen, as indicated in Fig. 286. From these spiracles air-tubes pass in a short distance and connect on each side of the body with the *spiracular trachea* (Fig. 286, s, Fig. 287, s) as we may call it. The air-tubes consist of two coats, with several short spiral threads wound around the tube (Fig. 288). These spiracular tracheæ begin at the posterior spiracle, and extend forward into the mesothorax, there subdividing into several branches. Branches from them pass to the two main *ventral* tracheæ (Fig. 286, *v*), and to the two main *dorsal* tracheæ (Fig. 286, *D*, Fig. 287, *D*). The main tracheal system in the abdomen, then, consists of six tubes, three on a side, extending along the abdomen. The pair of ventral tracheæ extend along the under side of the digestive canal; the dorsal tracheæ rest on the digestive canal. These six tubes are connected by anastomosing tracheæ, and, with their numerous subdivisions and minute twigs and the system of dilated tracheæ or air-sacs, an intricate network of tracheæ is formed.

The system of thoracic air-tubes is quite independent of the abdominal system, and not so easy to make out. The tubes arising from the two thoracic stigmata are not very well marked; they, however, send two well-marked tracheæ into the head (Fig. 286, *c*, Fig. 287, *c*), which subdivide into the ocular dilated air-tube (Fig. 286, *oc*, Fig. 287, *oc*) and a number of air-sacs in the front of the head.

The series of large abdominal air-sacs, of which there are five pairs (Fig. 287, 3–7), arise independently of the main tracheæ directly from branches originating from the spiracles, as seen in Fig. 286. They are large and easily found by raising the integument of the back. There is a large pair in the mesothorax (Fig. 287, 2) and two enormous sacs in the prothorax (Fig. 287, 1), sometimes extending as far back as the anterior edge of the mesothorax. All these sacs are superficial, lying next to the *hypodermis* or inner layer of the integument, while the smaller ones are, in many cases,

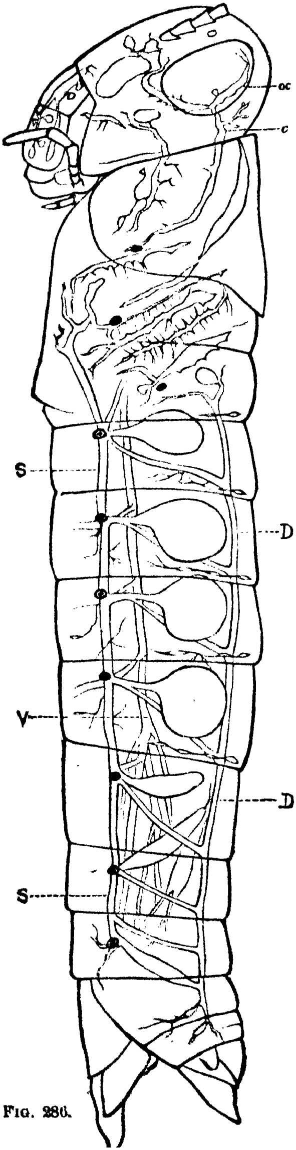


FIG. 286.

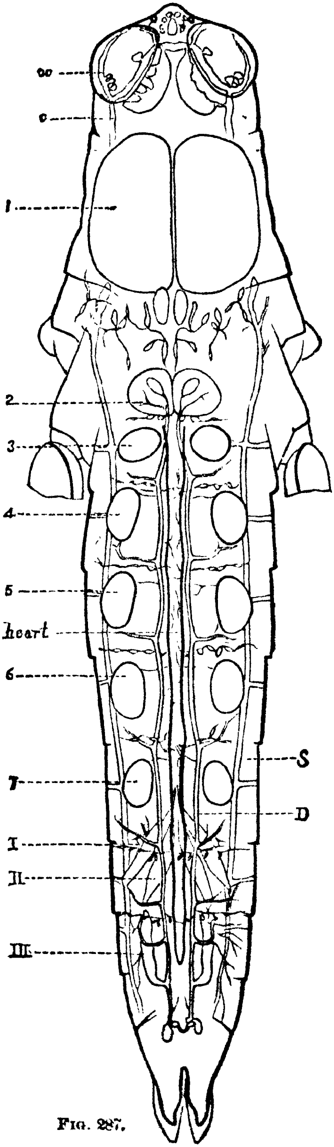


FIG. 287.

buried among the muscles. Besides the ordinary air-sacs, there is in the end of the abdomen, behind the ovaries, a plexus of six dilated air-sacs (Fig. 287, I, II, III), which are long, spindle-shaped, and are easily detected in dissecting.

There is a system of dilated tracheæ and about fifty air-sacs in the head.

In the legs two tracheæ pass down each side of the femora, sending off at quite regular intervals numerous much-branching, transverse twigs; there is one large and a very small trachea in the tibia, and the main one extends to the extremity of the last tarsal joint.

By holding the red-legged locust in the hand, one may observe the mode of breathing. During this act the portion of the side of the body between the spiracle and the pleurum (Fig. 278, *A*) contracts and expands; the contraction of this region causes the spiracles to open. The general movement is caused by the sternal moving much more decidedly than the tergal portion of the abdomen. When the pleural portion of the abdomen is forced out, the soft pleural membranous region under the fore and hind wings contracts, as does the tympanum and the membranous portions at the base of the hind legs. When the tergum or dorsal portion of the abdomen falls and the pleurum contracts, the spiracles open; their opening is nearly but not always exactly co-ordinated with the contractions of the pleurum, but as a rule they are. There were sixty-five contractions in a minute in a locust which had been held between the fingers about ten minutes. It was noticed that when the abdomen expanded, the air-sacs in the first ab-

Fig. 286.—Showing distribution of air-tubes (tracheæ) and air-sacs—side view of the body. *r*, main ventral trachea (only one of the two shown); *s*, left stigmatal trachea, connecting by vertical branches with *D*, the left main dorsal trachea; *c*, left cephalic trachea; *oc*, ocular dilated trachea. From the first, second, third, and fourth spiracles arise the first four abdominal air-sacs, which are succeeded by the plexus of three pairs of dilated tracheæ, I, II, III, in Fig. 287. Numerous air-sacs and tracheæ are represented in the head and thorax. The two thoracic spiracles are represented, but not lettered.

Fig. 287.—*D*, left dorsal trachea; *S*, left stigmatal trachea; I, II, III, first, second, and third pairs of abdominal dilated tracheæ, forming a plexus behind the ovaries; 1, pair of enormous thoracic air-sacs; 2, pair of smaller air-sacs; 3-7, abdominal air-sacs; *oc*, ocular dilated trachea and air-sacs; *c*, cephalic trachea. The relations of the heart to the dorsal tracheæ are indicated.—Drawn by Emerton from dissections by the author.

dominal ring contracted. This would indicate that the air rushes into the spiracles during the contraction of the abdomen, and that the air-sacs are not refilled until the spiracles are closed ; thus the air in the air-sacs is perhaps constantly changing.

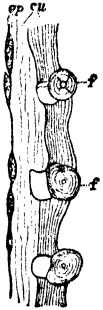


Fig. 288.—Longitudinal section of the trachea of *Hydrophilus piceus* or water-beetle. *ep*, epithelium; *cu*, cuticula ; *f*, spiral threads.—After Minot.

It is evident that the enormous powers of flight possessed by the locust, especially its faculty of sailing for many hours in the air, is due to the presence of these air-sacs, which float it up in the atmospheric sea. Other insects with a powerful flight, as the bees and flies, have well-developed air-sacs, but they are less numerous. It will be seen that, once having taken flight, the locust can buoy itself up in the air, constantly filling and refilling its internal buoys or balloons without any muscular exertion, and thus be borne along by favorable winds to its destination. It is evident that the process of respiration can be best carried on in clear, sunny weather, and that when the sun sets, or the weather is cloudy and damp, its powers of flight are lessened, owing to the diminished power of respiration. The finer structure of the trachea is seen in Fig. 288.

It is difficult to explain many of the actions of insects, from the fact that it is hard for us to appreciate their mental powers, instincts, and general intelligence. That they have sufficient intellectual powers to enable them to maintain their existence may be regarded as an axiom. But insects differ much in intelligence and also in the degree of perfection of the organs of sense. The intelligence of insects depends, of course, largely on the development of the organs of special sense.

The sense of sight must be well developed in the locust, there being two large, well-developed compound eyes, and three simple ones (*ocelli*), situated between the former, supplied with nerves of special sense.

Fig. 289 represents the eye of a moth greatly enlarged to show the finer structure.

The antennæ are, in the locust, organs of touch. The palpi are not only organs of touch, but probably, as in some other insects, are endowed with the sense of taste, enabling the locust to discriminate between the different kinds of food, and select that best adapted to suit its wants. It is possible that the labial nerves send branches of special sense to the tongue.

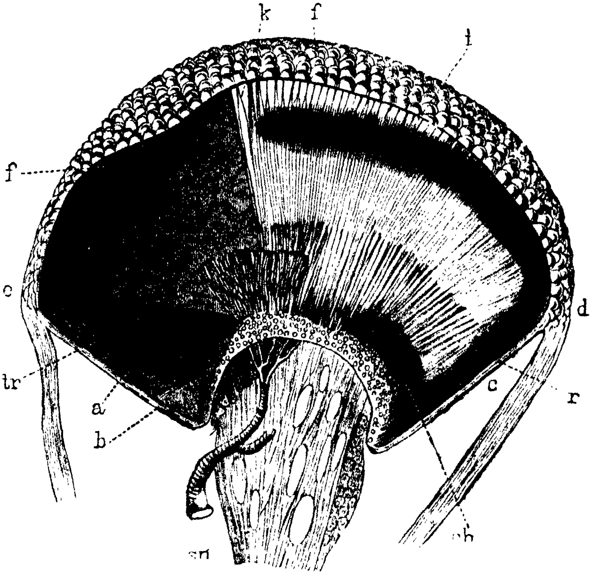


Fig. 289.—Longitudinal section of the facetted eye of a moth; the eye-capsule or sclera facetted externally (*f*), and sieve-like within, shows the rod-like ending of the optic nerve-fibres; *k*, layer of the crystalline lens; *i*, iris-like pigment zone; *ch*, choroid composed of pigment cells; *sn*, optic nerve; *tr*, trachea lost in fine bundles of fibrillæ.—After Leydig, from Graber.

The ears are well developed in the locust, and we know that the sense of hearing must be delicate, not only from the fact that a loud alarum with kettles and pans affects them, but the movements of persons walking through the grass invariably disturb them. Besides this, they produce a fiddling or stridulating sound by rubbing their hind legs against their folded wing-covers, and this noise is a sexual sound, heard and appreciated by individuals of the other sex. Any insect which produces a sound must be supposed to have ears to hear the sound produced by others of its species.

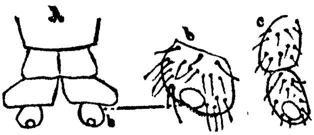


Fig. 290.—*A*, *b*, sense-organ on the abdominal appendages of a fly (*Chrysopila*); *c*, sense-organ on the terminal joint of palpus of *Perla*.—Author *del*.

In the antennæ, palpi, and abdominal appendages of different insects are seated minute sense organs of unknown functions, though probably either of smell or taste (Fig. 290).

The ears (or auditory sacs) of the locust are situated, one on each side, on the basal joint of the abdomen, just behind the first abdominal spiracle (Fig. 279). The apparatus consists of a tense membrane, the *tympanum*, surrounded by a horny ring (Fig. 291). " On the internal sur-

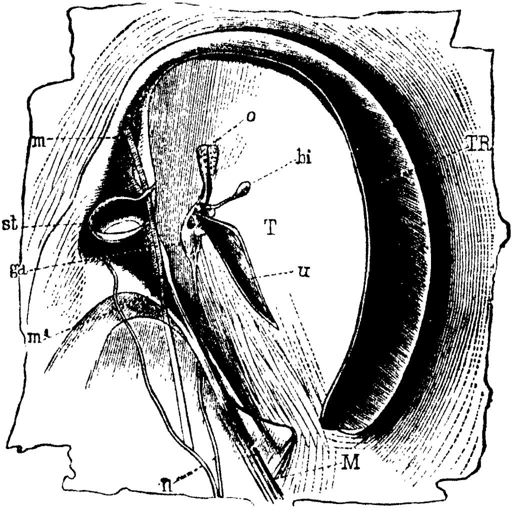


Fig. 291.—Ear of a locust (*Caloptenus italicus*) seen from the inner side. *T*, tympanum; *TR*, its border; *o*, *u*, two horn-like processes; *bi*, pear-shaped vesicle; *n*, auditory nerve; *ga*, terminal ganglion; *st*, stigma; *m*, opening and *m′* closing muscle of the same; *M*, tensor muscle of the tympanum-membrane.—After Graber.

face of this membrane are two horny processes (*ou*), to which is attached an extremely delicate vesicle (*bi*) filled with a transparent fluid, and representing a membranous labyrinth. This vesicle is in connection with an auditory nerve (*n*)

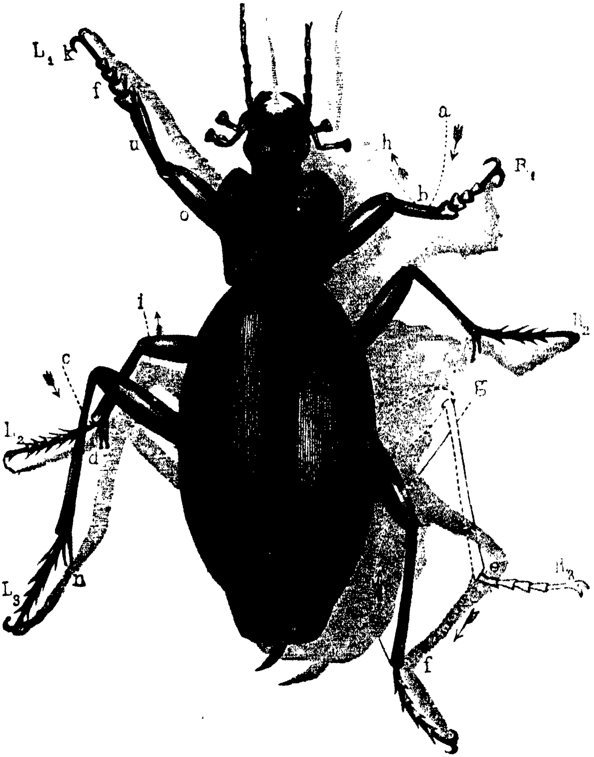


Fig. 292.—A Carabus beetle in the act of walking or running. Three legs (L^1, R^2, L^3), are directed forward, while the others (R^1, L^2, R^3), which are directed backward toward the tail, have ended their activity. *a b*, *c d*, and *e f* are curves described by the end of the tibiæ and passing back to the end of the body; *b h*, *d i*, and *f g* are curves described by the same legs during their passive change of position.—After Graber.

which arises from the third thoracic ganglion, forms a ganglion (*ga*) upon the tympanum, and terminates in the immediate neighborhood of the labyrinth by a collection of cuneiform, staff-like bodies, with very finely-pointed extremities (primitive nerve-fibres?), which are surrounded by loosely aggregated ganglionic globules." (Siebold's Anatomy of the Invertebrates.)

In walking, the locust, beetle, or, in fact, any insect, raises and puts down its six legs alternately, as may be seen by observing the movements of a beetle (Fig. 292). While the structure of the limb of a vertebrate and insect is not homologous, yet the mechanism or functions of the parts are in the main the same, as indicated in Figs. 293 and 294.

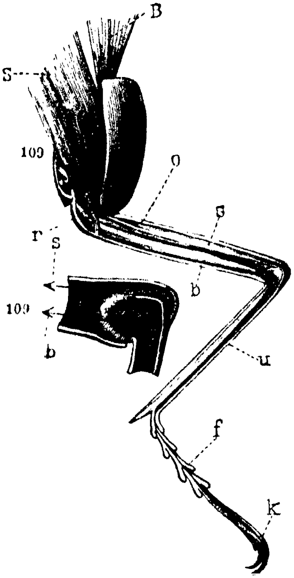


Fig. 293.—Section of the fore leg of a Stag beetle, showing the muscles. *S*, extensor, *B*, flexor of the leg; *s*, extensor; *b*, flexor of the femur; *o*, femur; *u*, tibia; *f*, tarsus; *k*, claw. 109, *s*, extensor, *b*, flexor of the femoro-tibial joint, both enlarged.—After Graber.

The footprints of insects are sometimes left in fine wet sand on the banks of streams or by the seaside.

In Fig. 295 the black dots are made by the fore, the clear circle by the middle, and the black dashes by the hind legs (Graber).

The wings are developed as folds of the integument, and strengthened by hollow rods called "veins;" their branches called "venures." There are in the wings of most insects six main veins—*i.e.*, the costal, the subcostal, median, submedian, internal, and anal. They are hollow and usually contain an air-tube, and a nerve often accompanies the trachea in the principal veins. The arterial blood from the heart (as seen in the cockroach by Moseley) flows directly into the costal, subcostal, median, and submedian veins; here it is in part aërated, and returns to the heart from the hinder edge of the wings through the hinder smaller branches and the main trunks of the internal and anal veins. So that the wings of insects act as lungs as well as organs of flight. For the latter purpose, the principal veins are situated near the front edge of the wing, called the *costa*, and thus the wing is strengthened when the most strain comes during the beating of the air in flight.

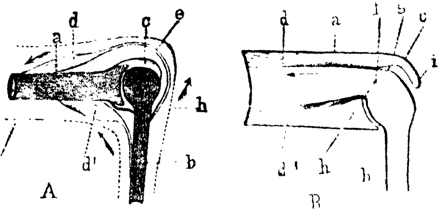


Fig. 294.—Diagram of the knee-joint of a vertebrate (*A*) and an insect's limb (*B*). *a*, upper, *b*, lower shank, united at *A* by a capsular joint, at *B* by a folding joint; *d*, extensor or lifting muscle; d^1, flexor or lowering muscle of the lower joint. The dotted line indicates in *A* the contour of the leg.—After Graber.

The wing of an insect in making the strokes during flight describes a figure 8 in the air. A fly's wing makes 330 revolutions in a second, executing therefore 660 simple oscillations.

The sexes are always distinct in insects, the only known exception being certain very low aquatic Arachnida called *Tardigrada*, in which both sexual glands occur in the same individual. The testes of the common red-legged locust form a single mass of tubular glands, resting in the upper side of the third, fourth, and fifth segments of the hind body. Figs. 296 and 297 represent this structure in other insects. The ovaries consist of two sets of about twenty long tubes, within which the eggs may be found in various stages of development. The eggs pass into two main tubes which unite to form the single oviduct which lies on the floor of the abdomen. Above the opening of the oviduct is the sebific gland and its duct. This gland secretes a copious supply of a sticky fluid, which is, as in many other insects, poured

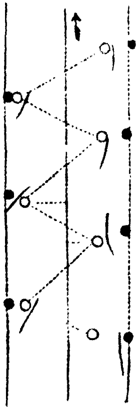


Fig. 295.—Foot tracks of *Necrophorus vespillo*. Natural size.—After Graber.

out as the eggs pass out of the oviduct, thus surrounding them with a tough coat.

The external parts consist of the ovipositor (Fig. 278, *B*, and Fig. 281), which is formed of two pairs of spines (*rhabdites*) adapted for boring into the earth; and of the egg-guide (Figs. 278 and 281, *eg*), a triangular flap guarding the under side of the opening of the oviduct.

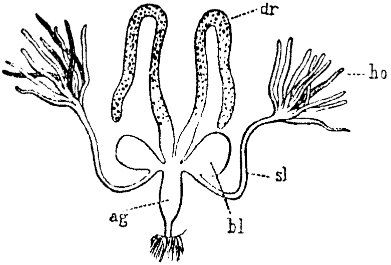


Fig. 296.—Male sexual apparatus of a bark-beetle. *sl*, vas deferens; *ho*, testis; *bl*, seminal vesicle; *ag*, ductus ejaculatorius.—After Graber.

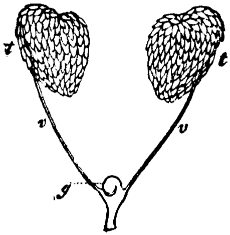


Fig. 297.—*t*, testis; **v**, vas deferens; *g*, seminal vesicle of *Acheta campestris*.—After Gegenbaur.

There is a remarkable uniformity in the mode of development of the winged insects. In general, after fertilization of the egg, a few cells appear at one end of the egg; these multiply, forming a single layer around the egg, this layer constituting the blastoderm. This layer thickens on one side of the egg, forming a whitish patch called the *primitive streak* or *band*. The blastoderm molts, sloughing off an outer layer of cells, a new layer forming beneath; the skin thus thrown off is called the serous membrane; the second germ-layer (ectoderm) then arises, and a second membrane (called amnion, but not homologous with that of vertebrates) peels off from the primitive band just as the appendages are budding out, so that the body and appendages of the embryo insect are encased in the amnion as the hand and fingers are encased by a glove. As seen in the accompanying Figs. 298–303, the

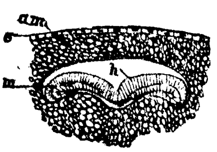


Fig. 298.—Section of Sphinx embryo, the germ immersed in the yolk; *s*, serous membrane; *am*, amnion; *h*, outer, *m*, inner germ-layer.

appendages bud out from the under side of the primitive band, and antennæ, jaws, legs, ovipositor (or sting), and the abdominal feet of caterpillars are at first all alike. Soon the appendages begin to assume the form seen in the larva, and just before the insect hatches the last steps in the elaboration of the larval form are taken.

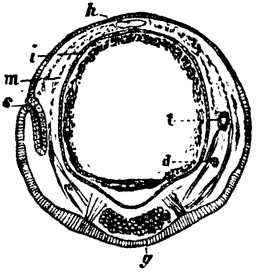


Fig. 299.—Embryo of Sphinx much more advanced. *h*, heart; *g*, ganglion; *i*, intestine; *m*, rudimentary muscular bands running to the heart; *s*, stigma and beginning of a trachea (*t*); *d*, a gland. This and Figs. 293-296 after Kowalevsky.

As to the development of the internal organs, the nervous system first originates; the alimentary canal is next formed; and at about this time the stigmata and air-tubes arise as invaginations of the outer germ-layer. The development of the salivary glands precedes that of the urinary tubes, which, with the genital glands, are originally offshoots of the primitive digestive tract. Finally the heart is formed.

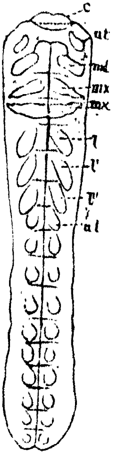


Fig. 300.—Primitive band or germ of a Sphinx moth, with the segments indicated, and their rudimentary appendages. *c*, upper lip; *at*, antennæ; *md*, mandibles; *mx*, *mx'*, first and second maxillæ; *l*, *l'*, *l''*, legs; *al*, abdominal legs.

When the insect hatches, it either cuts its way through the egg-shell by a temporary egg-cutter, as in the flea, or the expansion of the head and thorax and the convulsive movements of the body, as in the grasshopper, burst the shell asunder. The serous membrane is left in the shell, but in the case of grasshoppers the larva on hatching is still enveloped in the amnion. This is soon cast as a thin pellicle.

The principal change from the larval to the adult locust or grasshopper is the acquisition of wings. In such insects, then, as the *Orthoptera* and *Hemiptera*, in which the adults differ from the newly hatched larva mainly in the possession of wings, metamorphosis is said to be *incomplete*. In the beetle, butterfly, or bee, the metamorphosis is *complete;* the caterpillar, for example, is a biting insect, is voracious, and leads a different life from the quiescent, sleeping *pupa* or chrysalis, which takes no food; on the other hand, the imago or butterfly has mandibles, which are rudimentary, and incapable of biting, while the maxillæ, or "tongue," which were rudimentary in the caterpillar, become now greatly developed; and the butterfly takes liquid food and but little of it, while its surroundings and mode of life are entirely changed with its acquisition of wings. Thus the butterfly leads three different lives, differing greatly in structure, externally and internally, at these three periods, and with different environments.

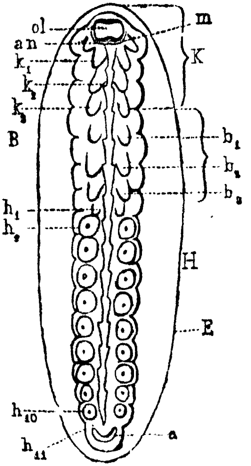


Fig. 801.—Embryo of a Water-beetle (*Hydrophilus*). *E*, egg; *K*, head; *ol*, upper lip; *m*, mouth; *an*, antennæ; k_1, mandibles; k_2, k_3, maxillæ; *B*, thorax; b_1, b_2, b_3, legs; h_1-h_{10}, ten pairs of rudimentary abdominal legs, of which all except h_1 disappear before the insect hatches; *a*, anus.—After Kowalevsky.

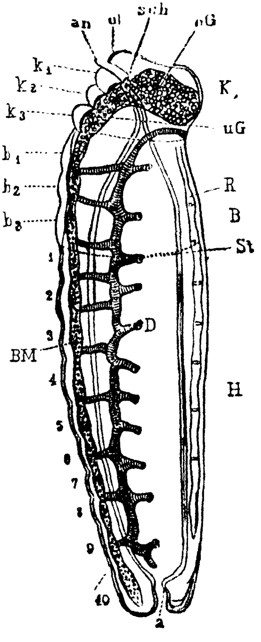


Fig. 802.—Profile view of embryo Honey-bee, lettering as in Fig. 801. *BM*, nervous cord; *oG*, brain; *D*, digestive canal; *sch*, the œsophagus; *St*, stigmatal openings of the tracheal system; *R*, heart.—After Blütschli.

Most caterpillars moult four or five times; at each moult the outer layer of the skin is cast off, the new skin arising from the *hypodermis*, or inner layer of the integument. The skin opens on the back behind the head, the caterpillar drawing itself out of the rent. In the change from the caterpillar to the chrysalis, there are remarkable transformations in the muscles, the nervous, digestive, and circulatory system, inducing a change of form, external and internal, characterizing the different stages in the metamorphosis.

While the changes in form are comparatively sudden in flies and butterflies, the steps that lead to them are gradual. How gradual they are may be seen by a study of the metamorphosis of a bee. In the nest of the humble or honey bee, the young may be found in all stages, from the egg to the pupa gayly colored and ready to emerge from its cell. It is difficult to indicate where the chrysalis stage begins and the larva stage ends, yet the metamorphosis is more complete—namely, the adult bee is more unlike the larva, than in any other insect.

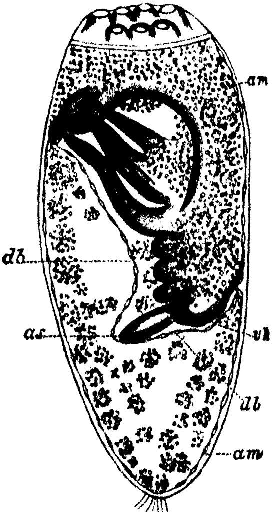


Fig. 303.—Embryo of the Louse. *am*, serous membrane; *db*, amnion; *as*, antennæ; *vk*, forehead.—After Melnikow.

Besides the normal mode of development, certain insects, as the plant-louse (*Aphis*), the bark-louse (*Coccus*), the honey-bee, the Polistes wasp, the currant saw-fly (*Nematus*), the gall-flies, and a few others, produce young from unfertilized eggs. Certain moths, as the silk-worm moth (*Bombyx mori*) and others, have been known to lay unfertilized eggs from which caterpillars have hatched. This anomalous mode of reproduction is called *parthenogenesis*, and fundamentally is only a modification of the mode of producing young by budding which is universal in plants, and is not unusual, as we have seen, among the lower branches of the animal kingdom. The object or design in nature, at least in the case of the plant-lice and bark-lice, as well as the gall-flies, is the production of large numbers of individuals, by which the perpetuity of the species is maintained.

Insects are both useful and injurious to vegetation. Were it not for certain bees and moths, orchids and many other plants would not be fertilized ; insects also assist in the cross-fertilization of plants. For full crops of many of our fruits and vegetables, we are largely indebted to bees, flies, moths, and beetles, which, conveying pollen from flower to flower, ensure the production of abundant seeds and fruits. Mankind, on the other hand, suffers enormous losses from the attacks of injurious insects. Within a period of four years, the Rocky Mountain locust, migrating eastward, inflicted a loss of $200,000,000 on the farmers of the West. In the year 1864, the losses occasioned by the chinch-bug in the corn and wheat crop of the valley of the Mississippi amounted to upward of $100,000,000. It is estimated that the average annual losses in the United States from insects are about $100,000,000. On the other hand, hosts of ichneumon flies and Tachina flies reduce the numbers and prevent undue increase in the numbers of injurious insects.

The number of species of insects is estimated to be about 190,000. Of these there are about 25,000 species of *Hymenoptera* (bees, wasps, etc.) ; about 25,000 species of *Lepidoptera* (butterflies and moths) ; about 24,000 *Diptera* (two-winged flies), and 90,000 *Coleoptera* (beetles) ; with about 4600 species of *Arachnida* (spiders, etc.), and 800 species of *Myriopoda* (millepedes, centipedes, etc.)

Insects are distributed all over the surface of the earth. Most of the species are confined to the warmer portions of the globe, becoming fewer in the number of species as we approach the North Polar regions. Many are inhabitants of fresh water ; a very few inhabit the sea.

Insects, so far as the records go, first appeared in the Devonian rocks ; these were *Neuroptera* and *Orthoptera*, such as May-flies and other forms which seem generalized in their structure. But if highly developed flying insects, belonging, at least the May-fly, to existing families, appeared in the Devonian period, it is reasonable to suppose that insects must have inhabited the dry land of the Silurian period.

Insects are divided into four sub-divisions or sub-classes—*i.e.*, the *Malacopoda*, the *Myriopoda*, the *Arachnida*, and the six-footed, winged insects, or *Hexapoda*. All agree in breathing by air-tubes, and in having in most cases a tri-regional arrangement of the segments of the body. By some authors the three higher groups are regarded as independent classes, but they are all modifications of a general insect form, with similar mouth-parts, a single pair of antennæ, when these organs are present, with no palpus to the mandibles, and with other characters which render the class *Insecta* equivalent to the class *Crustacea.*

Sub-class 1. Malacopoda.—This group is represented by a single animal, the strange *Peripatus* of tropical countries, in which the body is cylindrical, the integument, antennæ, and limbs soft, not chitinized, with the head not separate from the body, and bearing a pair of many-jointed extensible antennæ, with two pairs of rudimentary jaws (mandibles and maxillæ), and from fourteen to thirty-three pairs of feet (according to the species). This animal differs from other Arthropods in the two widely separated minutely ganglionated nervous cords sent backward from the brain; also in the minute, numerous tracheal twigs arising from numerous minute oval openings (rudimentary spiracles) situated irregularly along the median line of the ventral surface of the body. The feet are soft, fleshy, and end in two claws. Peripatus is viviparous. According to the description and figures of Mr. Moseley, the young develop much as in the chilopodous Myriopods (*Geophilus*), showing that *Peripatus* is nearer to the Myriopods than any other group. That it is a tracheate animal was also proved by Mr. Moseley; but owing to the nature of the nervous system and the minute tracheæ and their numerous irregular spiracular openings, with no chitinous edge, this form cannot be placed among the Myriopods. On the other hand, it has some features recalling the *Linguatulina* and *Tardigrada*, as seen in the soft clawed feet and short wrinkled segments. It is certainly not a worm, but, on the whole, connects the worms with the sucking Myriopods, and suggests that the insects may have descended from forms somewhat like *Peripatus*. *Peripatus iuliformis* inhabits the West Indies, and either *P. Edwardsii* Blanchard, or an undescribed species about four centimetres in length (with twenty-seven pairs of legs), inhabits the Isthmus of Panama. The name *Malacopoda* was proposed by De Blainville, who suggested that *Peripatus* connected the Myriopods with the Annelids. There is but a single genus, *Peripatus*.

Sub-class 2. Myriopoda.—The centipedes and millepedes are distinguished by their cylindrical body, the abdominal segments being numerous and similar to the thoracic segments, all provided with a pair of feet. The head is free, with a pair of antennæ, mandibles, and usually two pairs of maxillæ. The internal organization is simple, like that of the larvæ of insects. Some *Scolopendræ* are said to be viviparous.

Order 1. *Chilognatha.*—To this group belong the millepedes, *Julus*, etc. (Figs. 304–307). The first maxillæ are absent. The segments are round or flattened, and the feet are inserted near together, the sternum being undeveloped. In some forms (Fig. 304, *Spirostrephon Copei* Pack., from Mammoth Cave) the body is hairy. They are all harmless. The eggs are laid in large numbers an inch or two beneath the surface of the earth. They undergo total segmentation, and in a few days the larva (Fig. 305) hatches. At this time it bears a resemblance to a *Podura*, having but three pairs of feet, the third pair attached to the fourth thoracic segment. After a series of moults, new segments and new feet appear, and thus these Myriopods undergo a distinct metamorphosis. The species feed on dead, sometimes fresh leaves, and on fallen fruit.

Order 2. *Pauropoda.*—The two orders of Myriopods are connected by *Pauropus*, which by Lubbock is regarded as the type of a distinct order (*Pauropoda*). Our only species, *Pauropus Lubbockii* Pack. (Fig. 309), consists of six segments besides the head, and the young *Pauropus* has but

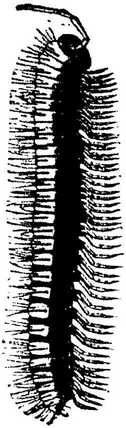


Fig. 304.—*Spirostrephon copei* of Mammoth Cave.

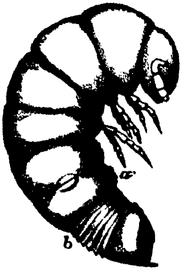


Fig. 305.—Larva of *Julus*. *a*, third abdominal segment, with the new limbs just budding out; *b*, new segments arising between the penultimate [illegible]—After Newport.

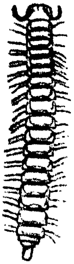


Fig. 306.—*Polydesmus erythropygus*—common Polydesmus.

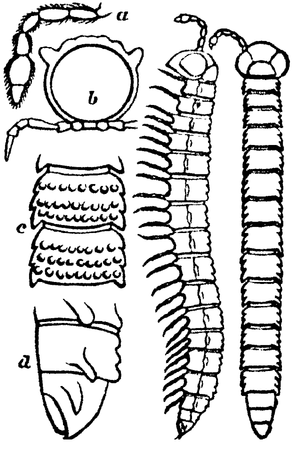


Fig. 307.—*Polydesmus cavicola*, from Utah, top and side view. *a*, antenna; *b*, a segment and leg; *c*, dorsal view of two segments showing ornamentation; *d*, side view of two terminal segments of the body—all magnified.

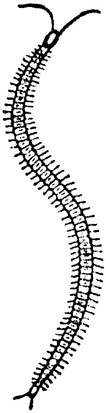


Fig. 308.—*Geophilus*. Natural size.

three pairs of feet, and in this and other respects resembles *Podura*. A second form, *Eurypauropus*, of Ryder, has six segments, with feet wholly concealed from above by the expanded segments.

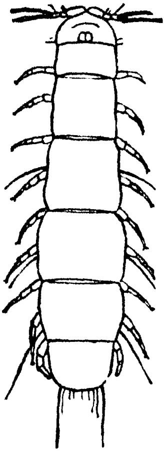


Fig. 309.—*Pauropus Lubbockii*. Much enlarged. Fig. 310 enlarged view of head and antennæ and first pair of feet.

Order 3. *Chilopoda.*—This group is represented by the centipede and *Lithobius*, in which the body is flattened, the sternal region being well developed. In *Geophilus* (Fig. 308, *G. bipuncticeps* Wood) and allies there are from thirty to two hundred segments. Our most common form is *Lithobius Americanus* Newport, found under logs, etc. The centipede (*Scolopendra heros* Girard) is very poisonous, the poison-sac being lodged in the two large fangs or first pair of legs. *S. gigantea* Linn., of the East Indies, is nine inches long. In *Cermatia* the body is short, with compound eyes in the head and remarkably long slender legs. *C. forceps* Rafinesque, of the Middle and Southern States, is said to be poisonous.

An aberrant, generalized form is *Scolopendrella*, in which the head and antennæ are like those of *Campodea*, a Thysanurous insect ; this is therefore a connecting link between the Myriopods and Hexapods.

Sub-class 3. Arachnida.—The bodies of spiders and scorpions, etc., are divided into two regions, a head-thorax and abdomen, the head being closely united with the thorax. There are no antennæ, only a pair of mandibles and a pair of maxillæ, with four pairs of legs. There are never any compound eyes. The young are usually like the adult, except in the mites, in which there is a slight metamorphosis. In all Arachnida there is a liver, this organ not being present in the winged insects.

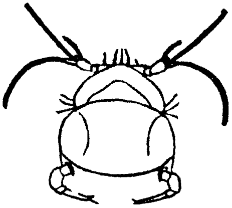


Fig. 310.—Head of *Pauropus Lubbockii*. Much enlarged.

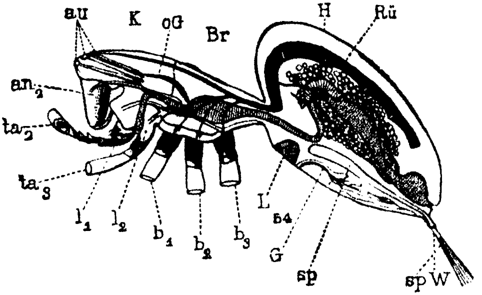


Fig. 311.—Anatomy of a spider, diagrammatic longitudinal section through the body. *au*, simple eyes and nerves leading to them from the brain (supra-œsophageal ganglion, *oG*); *an*$_2$, mandibles; *ta*$_2$, palpus of maxilla l_1; l_2, first pair of legs, b_1-b_3, succeeding pairs; *K*, head; *Br*, thorax; *H*, hind-body or abdomen; *Rü*, heart or dorsal vessel; *L*, lung in front of the opening of the oviduct *G*; the spinning-glands (*sp*) connect with the spinnerets, *sp W*. The digestive tract is shaded, and in the abdomen enveloped in the liver.—After Graber.

The type of the sub-class is the spider, which is characterized by the possession of two or three pairs of spinnerets, which are jointed appendages homologous with the legs. Besides tracheæ, spiders have a so-called lung (Fig. 311, L), composed of several leaves, into which the blood flows, and is thus aërated. In *Lycosa* the blood flows through the heart from the head backward. There is a great range of structure, from the lowest mites to the spiders, certain mites having no heart, no tracheæ, very rudimentary mouth-parts, and no brain, there being but a single ganglion in the abdomen.

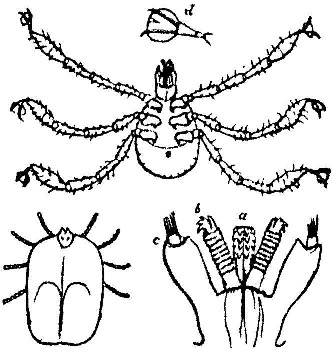


Fig. 312.—*Ixodes albipictus* from a partly domesticated moose. The tick natural size, gorged with blood, and its six-legged young, much enlarged. *a*, beak or mandibles armed with teeth; *b*, maxilla, and *c*, maxillary palpus; *d*, a foot with sucker and claws, enlarged.

Order 1. *Acarina.*—The mites are the simplest Arachnida, the body being oval in form, the head usually small, more or less merged with the thorax, while the latter is not differentiated from the abdomen. There is a slight metamorphosis, the mite when first hatched having but three pairs of legs, the fourth (and last) pair being added after a moult. A typical mite, though above the average size of the members of the group, is the tick (Fig. 312), *Ixodes albipictus* Pack. Closely allied to this is *Ixodes bovis* Riley, the cattle-tick (Fig. 313), which buries its head in the skin, anchoring itself firmly by means of the backward-pointing teeth of its jaws. Other examples of mites are the cheese and sugar mites (Fig. 314, *Tyroglyphus sacchari*).

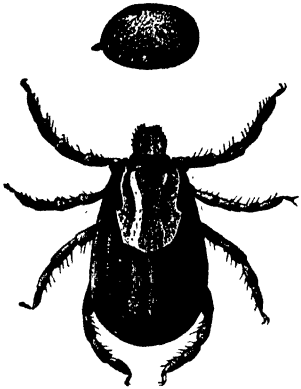


Fig. 313.—*Ixodes bovis*. Natural size and enlarged.

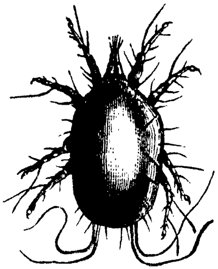


Fig. 314.—Sugar-mite. Much enlarged.

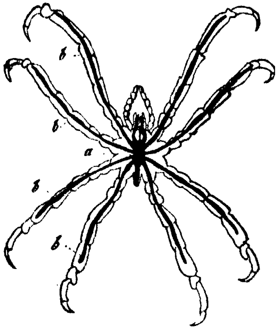


Fig. 315.—*Ammothoë pycnogonoides*. *a*, stomach with cœca (*b*, *b*, *b*, *b*) extending into the legs.—From Gegenbaur.

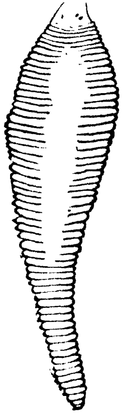


Fig. 316.—*Pentastoma tænioides*. Natural size.—From Verrill.

The sea-mites, *Pycnogonidæ*, are marine forms, without

air-tubes, with four pairs of long legs, into which cœcal prolongations of the stomach pass, as seen in Fig. 315.

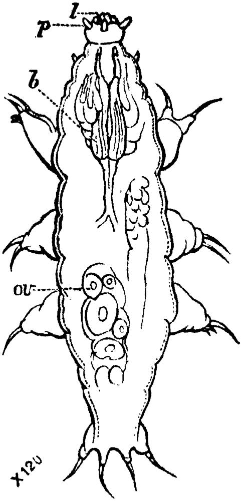


Fig. 317.—*Milnesium tardigradum,* x 120 times. *l*, mouth-parts; *b*, alimentary canal; *ov*, ovary.—After Doyere.

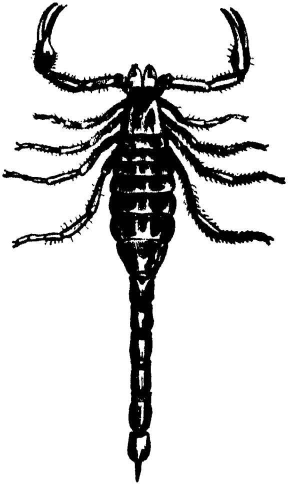


Fig. 318.—Carolina scorpion (*Carolinianus*). Natural size.

The lowest mites comprise remarkable worm-like *Acarina*, called *Linguatulina*. The young are mite-like, the body spherical, with boring jaws, and two pairs of short-clawed feet. *Pentastoma* (Fig. 316) occurs in the lungs and liver of man, and in horses and sheep.

The *Tardigrada* or bear animalcules (Fig. 317) are a step higher in the scale of mite life. In these singular beings the sexual glands exist in the same individual.

Macrobiotus Americanus Packard is common in sphagnum swamps. Like the Rotatoria, these low mites **are capable of revivifying after being apparently dead and dried up.**

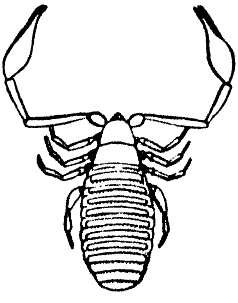


Fig. 319.—*Chelifer cancroides.* Magnified.

Order 2. *Pedipalpi.*—This group embraces the scorpion (Fig. 318), the false scorpions (Fig. 319), the whip scorpions, and the harvest-man (*Phalangium*). In all these forms the abdomen is plainly segmented, the segments not being visible in the mites or spiders. Usually the maxillary palpi are much enlarged, and end in claws. The scorpion is viviparous, the young being brought forth alive. The young scorpions cling to the back of the mother. The sting of the scorpion is lodged in the tail, which is perforated, and contains in the bulbous enlargement an active poison. Though producing sickness, pain, and swelling in the arm, the sting of the scorpion is seldom fatal.

The little false-scorpions (*Chelifer*, Fig. 319) often occur in books, under the bark of trees, and under stones. The whip-scorpion is confined to warm countries. *Thelyphonus giganteus* Lucas occurs in New Mexico and Mexico. Its abdomen ends in a long lash-like appendage. Its bite is poisonous. The harvest-men, or daddy-long-legs, are common in dark places about houses. They feed on plant-lice. Our common species is *Phalangium dorsatum* Say.

Order 3. *Araneina.*—The spiders are always recognizable by their spherical abdomen, attached by a slender pedicel to the head-thorax. They breathe, like the scorpions, both by lungs as well as by tracheæ, and the young resemble the parent in having four pairs of feet.

The development of the spider has some peculiarities not found in the higher insects. The egg undergoes total segmentation. The germ is somewhat worm-like, as in Fig. 320, then, as in *C*, the primitive band forms, with head and tail end much alike. Afterward (Fig. 321) the head accelerates in development, and the appendages begin to bud out, six pairs of abdominal limbs appearing and then totally disappearing, except the three pairs of spinnerets, as if the spiders were descended originally from some Myriopod-like form. The mandibles are vertical, and end in hollow points, through which the poison exudes, the two poison-glands being situated in the head. The male spider is usually much smaller than the female; the latter lay their eggs in silken cocoons. The tarantula (*Lycosa*) usually lives in holes in the ground, and sometimes conceals the opening by covering it with a few dead leaves. Our largest spider is *Nephila plumipes* of the Southern States. The common garden spider is *Epeira vulgaris* Hentz. It lives about houses and in gardens; its geometrical web is very regular. The large trap-door spider (Mygale) has four lung-sacs instead of two, as in the other spiders, and only two pairs of spinnerets. *Mygale Henzii* Girard inhabits the Western plains and Utah; *Mygale avicularia* Linn. of South America is known to seize small birds, and suck their blood. There are probably about six or eight hundred species of spiders in North America; their colors are often brilliant, and sometimes, from the harmony in their coloration with that of the flowers in which they hide, or the leaves on which they may rest, elude the grasp of insectivorous birds.

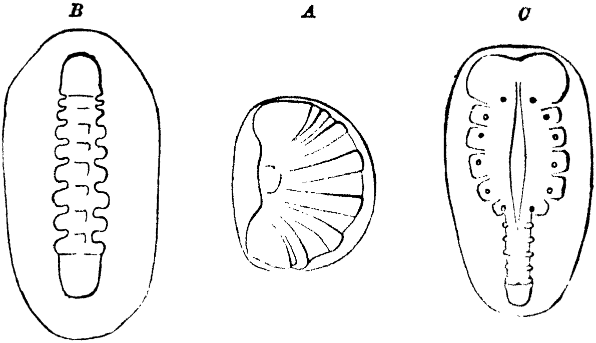


Fig. 320.—Development of the Spider.—*A*, worm-like stage; *B*, primitive band; *C*, the same more advanced, with rudiments of limbs.

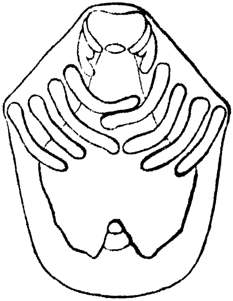


Fig. 321.—Embryo Spider, still more advanced. This and Fig. 320 after Claparède.

Sub-class 4. Hexapoda.—The triregional division of the body is better marked in the genuine winged insects than in the Myriopods and spiders. They have compound as well as simple eyes; two pairs of wings; three pairs of thoracic legs; often a pair of jointed abdominal appendages, besides the ovipositor or sting which morphologically represents three pairs of legs.

There are eight orders, forming two series: first, the *Heterometabola*, comprising the *Thysanura*, *Neuroptera*, *Orthoptera*, *Hemiptera*, and *Coleoptera*, in which the metamorphosis is either incomplete or complete; the body shows a tendency to become flattened; the prothorax is usually large and flattened; the mouth-parts (except in the *Hemiptera*) adapted for biting. There are a number of wingless forms.

The second series of orders, or *Metabola*, comprising the *Diptera*, *Lepidoptera*, and *Hymenoptera*, usually have a cylindrical body, with the prothorax small, the mouth-parts often adapted for sucking or lapping up liquid food; with a complete metamorphosis, the larva being worm-like, cylindrical, very unlike the adult.

Order 1. *Thysanura.*—The spring-tails (*Podura*) and bristle-tails (*Lepisma*) represent this group. They are wingless, with some affinities to the Myriopods, and the typical form *Campodea* (Fig. 324) is regarded as the ancestral form of the six-footed insects, as it is a generalized type, and forms like it may have been the earliest insects to appear.

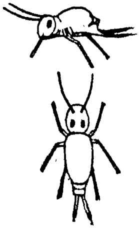


Fig. 322.—*Smynthurus*, a spring-tail, Enlarged.

In *Podura*, the spring-tail, and also in *Smynthurus* (*Smynthurus quadrisignatus* Pack., Fig. 322), the characteristic organ is a forked abdominal appendage or "spring," held in place by a hook; when released the spring darts backward, sending the insect high in the air.

Our commonest Poduran is *Tomocerus plumbeus* Linn. (Fig. 323), found all over the northern hemisphere in North America and Europe. The snow-flea, *Achorutes nivicola* Fitch is blue-black, and is often seen leaping about on the snow in forests.

The Podurans belong to the suborder *Collembola;* the higher forms, which bear a greater resemblance to the larvæ of Neuropterous insects and to the young cockroach, are the *Cinura*, to which belong the genera *Campodea* (Fig. 324), *Lepisma*, and *Machilis*.

In these *Thysanura* there is no spring, but the tail ends in two or three bristles; and in *Machilis*, the highest form, there are compound eyes; in all there are jointed abdominal appendages, which structures are unique among Hexapodous insects. *Campodea Americana* Packard is a small white slender form, with long, many-jointed antennæ, and two long, slender jointed caudal appendages. It lives under stones, and *C. Cookei* Packard lives in Mammoth Cave.

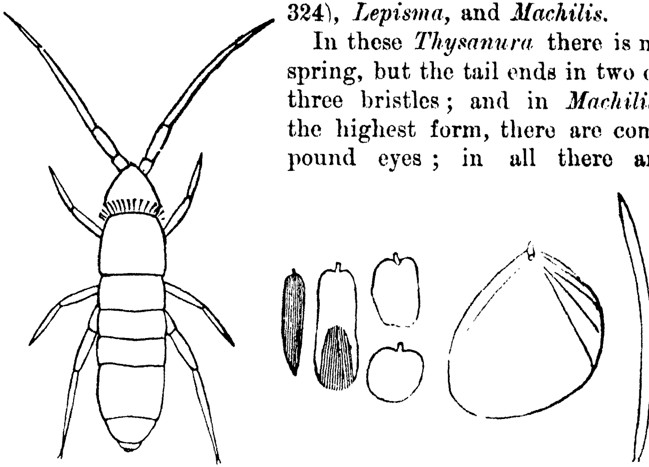


Fig. 323.—A Poduran (*Tomocerus*) and its scales. Much enlarged.

Order 2. *Neuroptera.*—This group of net-veined insects is interesting from the fact that the existing families are widely separate, owing to the geological extinction of intermediate links found fossil in the Devonian and Carboniferous strata. The mouth-parts are free, adapted for biting; the wings are broad, the hinder pair sometimes larger than the front pair, and both pairs are finely net-veined. The

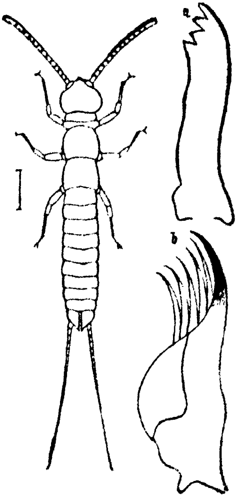


Fig. 324. — *Campodea*. *a*, mandibles; *b*, maxilla.

metamorphosis is either complete or incomplete. Many of the species are aquatic. There are ten existing families, and certain species of most of these families resemble or anticipate the higher orders that succeeded them in time. Thus the caddis-flies would be easily mistaken for small moths; the *Mantispa* mimics *Mantis*, the *Psocus* mimics the plant-lice, and the white ants which appeared in the Coal Period foreshadow the genuine ants, which first appeared in the Tertiary Period, wonderfully in form as well as in the extreme differentiation of the individual, involving a complicated colony with numerous members of the entomological body politic.

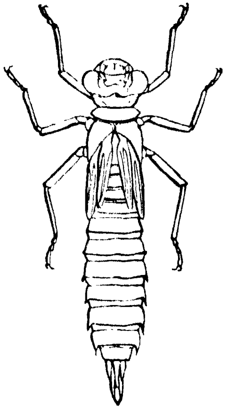


Fig. 325.—Pupa of a Dragon-fly (*Eschna*)

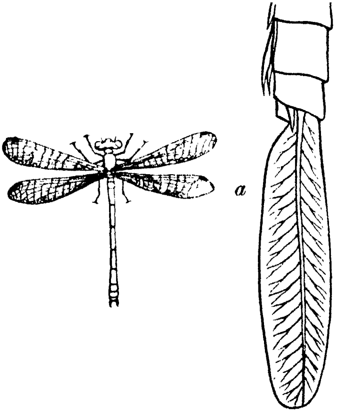


Fig. 326.—*Agrion*, natural size, and *a*, its larval gill, much enlarged.

As many of the larval Neuroptera live in the water, the various forms of external gills are of high interest. In the case-worms, which construct tubes of sand, bits of leaves, etc., the gills are slender filaments permeated by air-tubes and situated along the side of the body. In the larval and pupal dragon-fly (Fig. 325) the water passes into the intestine, where there are folds rich in minute tracheal branches. In the smaller dragon-flies, such as *Agrion* (Fig. 326), there are three long, leaf-like gills, interpenetrated by air-tubes.

In the May-fly (Fig. 327) the leaf-like gills grow out from the sides of the body. In the larval and pupal *Perla* (Fig. 328), tufts of gills are situated on the under side of the prothorax, and in the adult winged *Pteronarcys* these gills are retained. Both an European and Brazilian Caddis-fly has been found to possess gills in the winged condition.

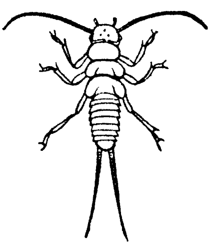
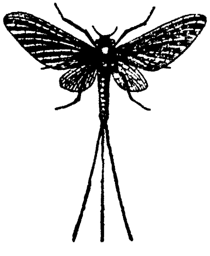


Fig. 328.—*Perla*, larva.



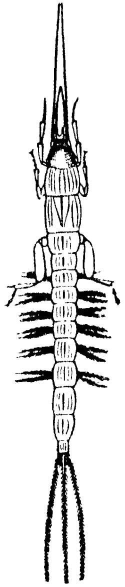


Fig. 327.—May-fly and larva, the latter enlarged.

The habits of the Neuroptera are most interesting; the ant-lion in the larval state constructs a pitfall for unwary insects. Its metamorphosis is complete, as is that of the Aphis-lion (Fig. 329, *Chrysopa oculata* Say, adult and eggs).

As an example of mimicry among insects is *Mantispa* (Fig. 330), which, in its raptorial fore-legs, strikingly resembles the Orthopterous *Mantis* (Fig. 333).

The white ants top the Neuropterous series; they live in stumps and fallen trees, and in the tropics do much harm by undermining the sills of houses, and destroying furniture, books, etc. The colonies are very large and populous. In our *Termes flavipes* there are males and females, workers and soldiers; the workers being small, ant-like, with small round heads, while the soldiers have large square heads, with long

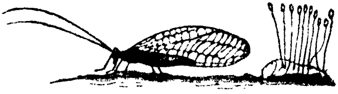


Fig. 329.—*Chrysopa* and group of stalked eggs.

jaws; the pupæ are active. Fritz Müller found in Brazil that one species of *Termes* was differentiated into six different kinds of individuals: viz., a set of winged and wingless females; winged and wingless males; workers and soldiers. A male always lives with a female, and a wingless male and female may, on the death of a winged normal male and female, replace them. He found a male (king) living with thirty-one complemental females. In *Calotermes* there are no workers, in *Anoplotermes* no soldiers. *Termes bellicosus* Smeathman, of the west coast of Africa, builds conical hills six feet or more in height.

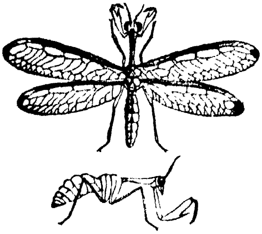


Fig. 330.—*Mantispa interrupta* Say; and side view of the same without wings. Natural size.—Emerton *del.*

Order 3. *Orthoptera.*—The insects of this group, so called from the straight-edged fore wings of the grasshoppers, locusts, crickets, etc., is characterized by their net-veined wings and incomplete metamorphosis; they are connected closely with the Neuroptera by the ear-wig (*Forficula*).

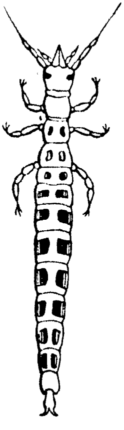


Fig. 331.—Freshly-hatched larva of *Mantispa styriaca*. Enlarged.

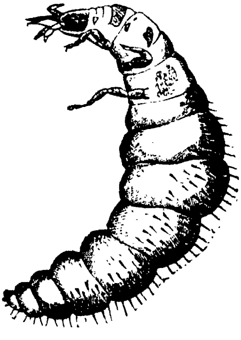


Fig. 332.—Larva of the same, but older, before the first moult. Enlarged.—After Brauer.

Organs of hearing may be situated either on the fore legs, as in the green grasshoppers, katydids, or at the base of the abdomen, as in the locusts. Most *Orthoptera* have a large ovipositor by which they burrow in the earth or into soft wood, and deposit their eggs singly or in masses. *Mantis* (Fig. 333) lays its eggs in a cocoon-like mass.

Many Orthoptera, as the crickets, green grasshoppers, katydids, etc., and locusts, produce loud, shrill sounds, which are sexual calls. They stridulate in three ways—*i.e.*, first, by rubbing the base of one wing-cover on the other (crickets and green grasshoppers); second, by rubbing the inner surface of the hind legs against the outer surface of the front wings (some locusts); third, by rubbing together the upper surface of the front edge of the hind wings and the under surface of the wing-covers during flight (some locusts).

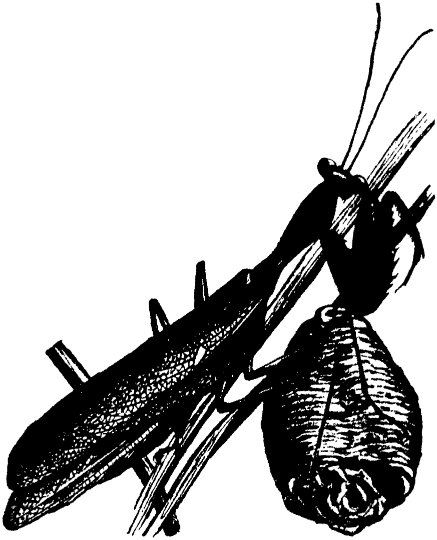


Fig. 333.—An African *Mantis*, or soothsayer, with its egg-mass.—From Monteiro's Angola.

Order 4. *Hemiptera.*—Insects of this group are called bugs. They all (except the bird-lice and *Thrips*) have sucking mouth-parts, the mandibles and first maxillæ are bristle-like, and ensheathed by the labium or second maxillæ. There are no palpi except in Thrips and the bird-lice. The metamorphoses are incomplete, the larva being like the adult, except that the wings are absent. Many bugs secrete a disagreeable fluid from glands seated in the metathorax. The lice are low, wingless parasitic *Hemiptera.* The squash-bug (Fig. 334, *Coreus tristis*) and chinch-bug (*Blissus leucopterus* Uhler) are types of the order.

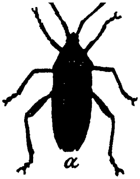


Fig. 334. — *Coreus tristis*, squash-bug.

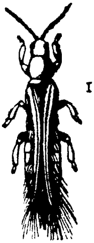


Fig. 335.— *Thrips.*

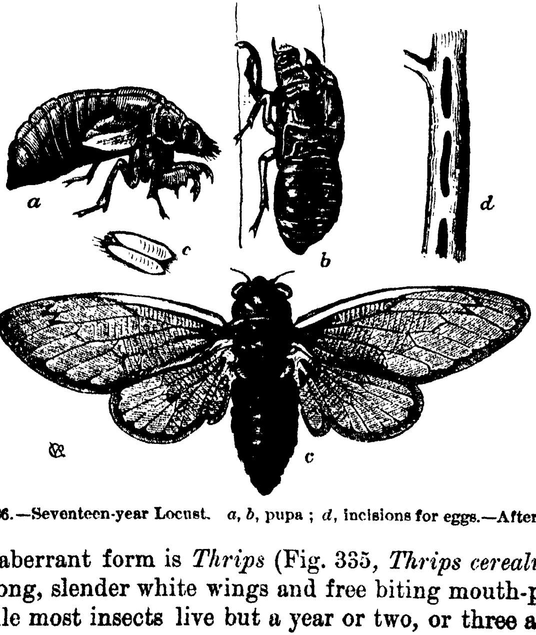


Fig. 336.—Seventeen-year Locust. *a, b,* pupa ; *d,* incisions for eggs.—After Riley.

An aberrant form is *Thrips* (Fig. 335, *Thrips cerealium*), with long, slender white wings and free biting mouth-parts.

While most insects live but a year or two, or three at the most, the seventeen-year locust (*Cicada septemdecim* Linn., Fig. 336) lives over sixteen years as a larva, finishing its transformations on the seventeenth ; there is also, according to Riley, a thirteen-year variety of this species.

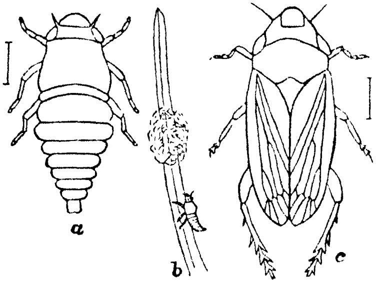
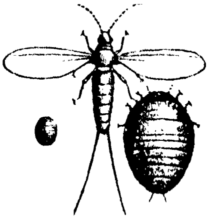


Fig. 337.—Spittle insect. *a*, larva, enlarged ; *b*, its natural size.



g. 338.—Cochineal insect, male ; female natural size and enlarged.

The froth insect (*Ptyelus lineatus*, Fig. 337) abounds on grass in early summer. The cochineal insect (*Coccus cacti*) belongs to the *Coccidæ*, or bark-lice ; the dried female is used as a dyestuff, and abounds in Central America.

The plant-louse (Fig. 339, *Aphis mali* Fabr.) is provided with two tubes on the hind-body from which honey-dew drops, which attracts ants, wasps, etc. In summer the plant-lice reproduce asexually, and as there may be nine or ten generations, one virgin aphis may become the parent of millions of children and grand-children.

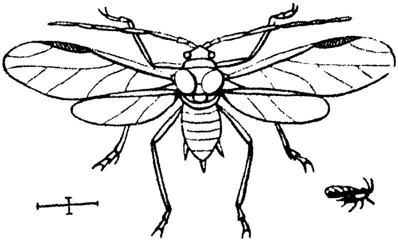


Fig. 339.—Apple Aphis. Natural size and enlarged.

Order 5. *Coleoptera.*—The beetles form a homogeneous and easily circumscribed group, all having the fore-wings thickened, not used in flight, and forming sheaths (*elytra* or wing-covers) for the hinder pair. The mouth-parts are free and adapted for biting. The metamorphosis is complete. The young or larvæ of beetles are called grubs. Examples of beetles and their transformations are the pine weevil (Fig. 340, *Pissodes strobi* Peck.) and the June beetle (Fig. 341, *Lachnosterna fusca* Fröhl.). The oil beetle is remarkable for passing through three larval stages (Fig.

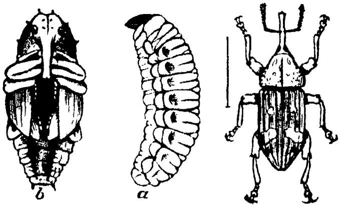


Fig. 340.—Pine weevil. *a*, larva; *b*, pupa.

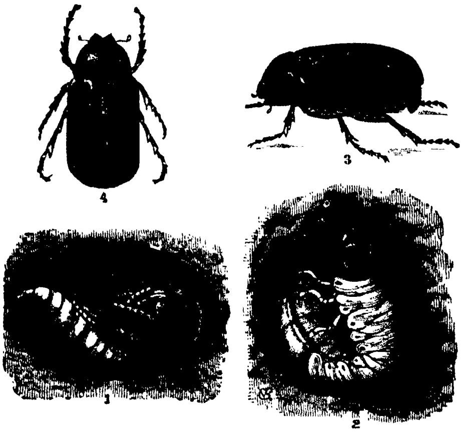


Fig. 341.—June Beetle and its transformations. 1, pupa; 2, larva.—After Riley.

342, *Meloë angusticollis* Say), the first larva being minute and parasitic on bees, sucking their blood, while in the second and third stages it feeds on the pollen mass designed for the young bees.

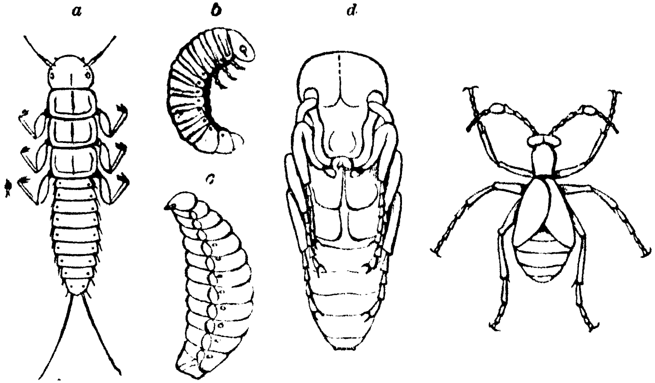


Fig. 342.—Oil Beetle. *a*, first larva; *b*, second larva; *c*, third larva; *d*, pupa.

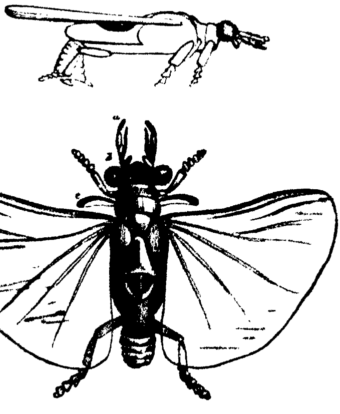


Fig. 343.—*Stylops childreni*, male, dorsal and side view. Much enlarged.

The blister beetles (*Lytta marginata*) undergo a similar series of transformations called a hypermetamorphosis.

The most aberrant of beetles is *Stylops* (Figs. 343 and 344, *S. childreni* Westwood), the male of which has minute fore wings. The female is wingless, grub-like, imperfectly developed, and is viviparous, the young issuing from her body

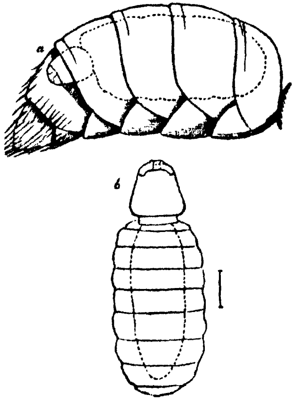


Fig. 344.—*Stylops childreni*, female. *a*, parasitic in the abdomen of a bee; *b*, top view of the same. Much enlarged.

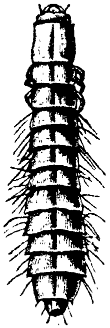


Fig. 345.—*Astraptor illuminator*, larva.

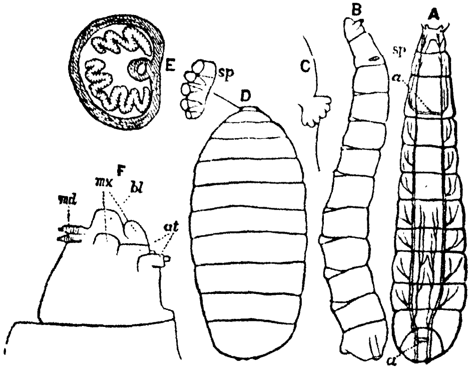


Fig. 346.—The early stages of the common House-fly. *A*, dorsal and side view of the larva; *a*, air-tubes; *sp*, spiracle. *C*, the spiracle enlarged. *F*, head of the same larva, enlarged; *bl*, labrum (?); *md*, mandibles; *mx*, maxillæ; *at*, antennæ. *E*, a terminal spiracle much enlarged. *D*, puparium; *sp*, spiracle. All the figures much enlarged.

in all directions. A few beetles are phosphorescent. Such are the fire-flies, the cucuyo of the West Indies, the glow-worm, and certain grubs, such as *Astraptor illuminator* (Fig. 345), *Melanactes*, and the young of a snapping beetle.

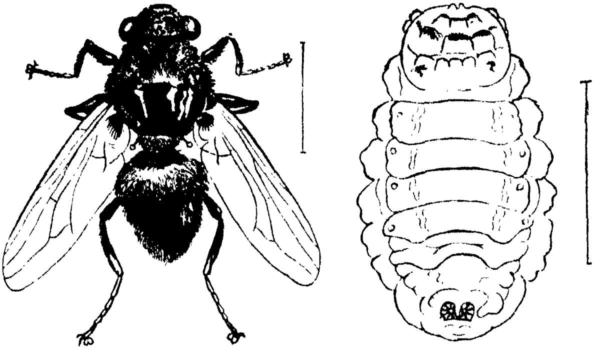


Fig. 347.—Bot-fly of the ox and its larva.

We now come to the second series of orders, the *Metabola.*

Order 6. *Diptera.*—The common house-fly (Fig. 346) is a type of this division, all the members of which have but two wings, while the tongue is especially developed for lapping up liquids. The common house-fly lives one day in the egg state, from five days to a week as a maggot, and from five to seven days in the pupa state. It breeds about stables.

The Tachina-fly is beneficial to man, from its parasitism in the bodies of caterpillars and other injurious insects.

The bot-fly (Fig. 347, *Hypoderma bovis* DeGeer) is closely allied to the house-fly, but the maggot is much larger. The larval bot-fly of the horse lives in the stomach, that of the sheep in the frontal sinus.

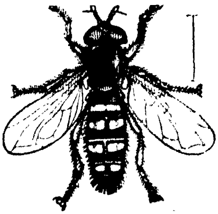


Fig. 348.—*Syrph*
Say.

The Syrphus flies (Fig. 348, *Syrphus politus* Say) mimic wasps ; they are most useful in devouring aphides.

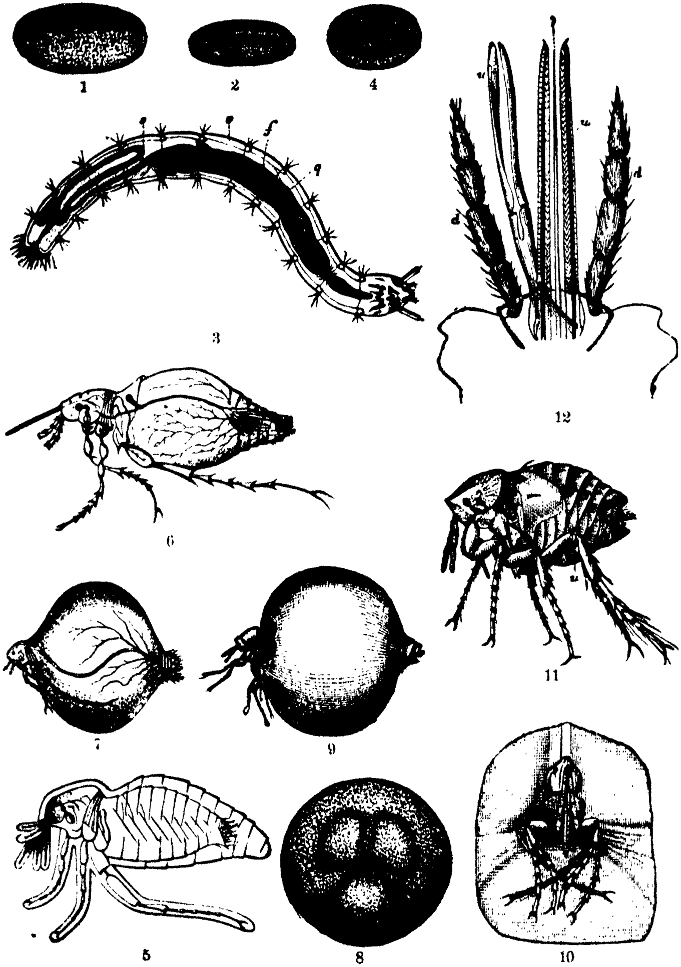


Fig. 349.—Metamorphosis of *Sarcopsylla penetrans*, or jigger, which lives in the toe of the natives of tropical America. 1, egg; 2, embryo; 3, larva; 4, cocoon; 5, pupa: 6, fecundated female; 7, the same on the third day from its entrance under the skin of its human host; 8, the same after several days' residence in the skin of its host; 9, fully grown female magnified four times; 10, head of the same still more enlarged; 11, the female before it has entered the skin of its host; 12, the mouth-parts, much enlarged; *m*, mandibles; *d*, maxillary palpi; *u*, under-lip or labium.—After Karsten and Guyon.

The fleas (349) are wingless flies, allied to winged forms intermediate between the house-flies and crane-flies.

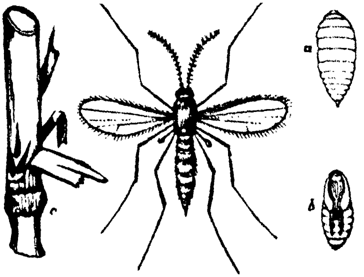


Fig. 350.—Hessian-fly. *a*, larva; *b*, pupa; *c*, incision in wheat stalk for larva.—After Fitch.

In the two-winged gall-flies (Fig. 350, *Cecidomyia destructor* Say, or Hessian-fly) the body is small and slender, with long antennæ. The crane-flies (*Tipula*) are large flies, standing near the head of the order, and, like the flea and gall-fly, the chrysalis is enclosed in a cocoon, there being no puparium or pupa-case, as in the lower flies. Lastly, we have the musquito (Figs. 351 and 352), whose larva is aquatic, and breathes by a process on the end of the body, containing a trachea.

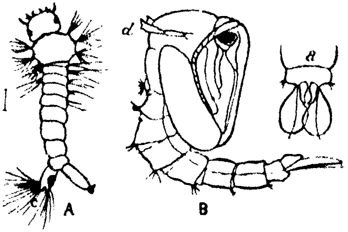


Fig. 351.—*A*, larva; *c*, its respiratory tube. *B*, pupa; *d*, respiratory tube. *a*, two paddles at the end of the body.

Order 7. Lepidoptera.—The butterflies and moths form a well-defined group, and are known by their scaly bodies (Fig. 353), the spiral maxillæ or tongue, rolled up between the two large labial palpi, and their usually broad wings. As the butterfly, the type of the order, has been described at some length, we will only enumerate some of the

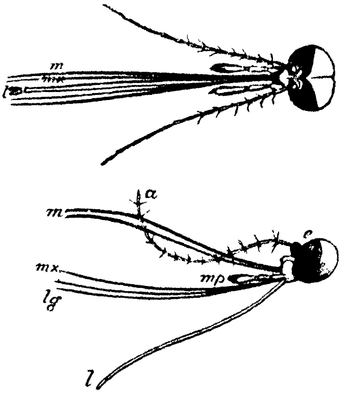


Fig. 352.—Head of Mosquito enlarged. *a*, antennæ; *m*, mandibles; *mx*, maxillæ; *mp*, maxillary palpi; *lg*, labium.

typical forms. The lowest group are the plume-moths (*Pterophorus*), in which the wings are fissured. Above them stand the clothes and grain moths (Figs. 354 and 355), which are minute moths with narrow wings.

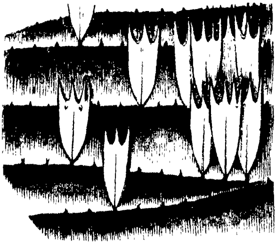


Fig. 353.—Showing mode of arrangement of the scales on the wings of a Moth.

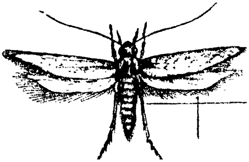


Fig. 354.—*Angoumois*, Grain Moth.

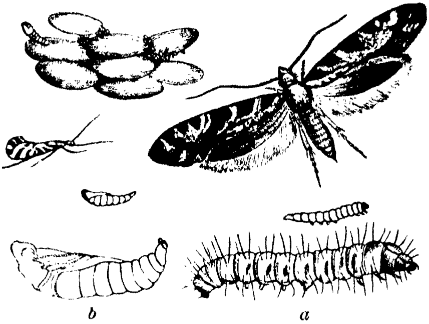


Fig. 355.—Grain Moth, *Tinea granella*. *a*, larva ; *b*, pupa, nat. size and enlarged ; *c*, grain of wheat held together by a web.—After Curtis.

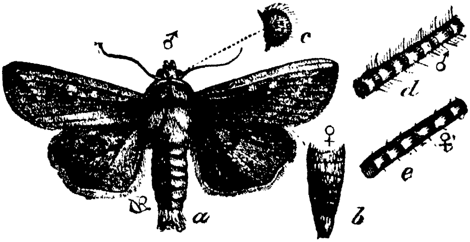


Fig. 356.—Army-worm Moth. *a*, male ; *b*, female; *c*, eye ; *d*, male ; *e*, portion of female antenna. Much magnified.—After Riley.

The larger moths are represented by the canker-worm, the grass army-worm (Fig. 356), and the cotton army-worm (Fig. 357), so destructive to vegetation; the silk-worm moth (*Bombyx mori* Linn.), of the Old World, and the American silk-worm (*Telea Polyphemus* Linn.). Certain species of the silk-worm family, called basket-worms (*Œceticus*), live in cases constructed of short or long strips (Fig. 358). Our native species is *Thyridopteryx ephemeræformis* Haworth.

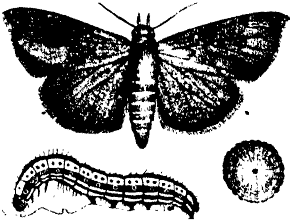


Fig. 357.—Egg, caterpillar, and moth of *Aletia argillacea*, the Cotton Army-worm.

The hawk-moths (*Sphinx*) are distinguished by their large size and very long tongue. The butterflies differ from the moths in having knobbed antennæ, while the chrysalides are often ornamented with golden or silvery spots.

Order 8. Hymenoptera.—The bees stand at the head of the insect series in perfection and specialization of parts, especially the organs of the mouth, and from the fact that in the course of the metamorphosis from the larva to the pupa the first abdominal segments become transferred to the thorax—a striking instance of the principle of transfer of parts headward. In the large head, spherical thorax, and short, conical abdomen, the bees are opposed to the dragon-flies and other Neuroptera, in which the abdomen is long, the thorax composed of three homogeneous segments, and the mouth-parts only adapted for biting. In the bee there is a marked differentiation of the parts of

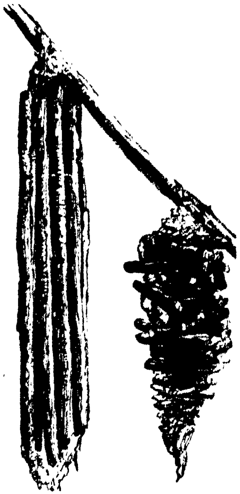


Fig. 358.—Cases of African Basket-worms. Natural size.

the first and second maxillæ; the tongue or fleshy prolongation of the second maxillæ (*labium*, see Fig. 359, *g*) being very long and adapted for lapping up liquid food in the bottom of flowers.

The *Hymenoptera* are represented by the saw-flies, the gall-flies, the ichneumon-flies and the ants, the sand-wasps, mud-wasps (Fig. 368), paper-making wasps, and bees.

The lowest family is the *Uroceridæ*, or horn-tails (Fig. 360, larva of *Tremex columba* Linn.), whose fleshy white larvæ bore in trees. The adults are large, with a long, saw-like ovipositor. In the saw-flies (*Tenthredinidæ*, Fig. 361, the pear-slug, *Selandria cerasi* Peck) the larva strongly resembles a caterpillar, having eight pairs of abdominal feet.

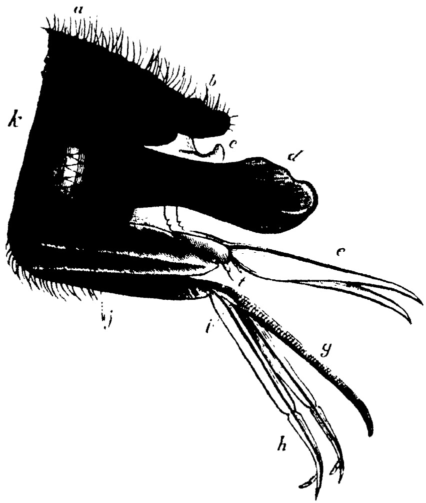


Fig. 359.—Side view of the front part of the head of the Humble Bee. *a*, clypeus covered with hairs; *b*, labrum; *c*, the fleshy epipharynx partially concealed by the base of the mandibles (*d*); *e*, lacinia or blade of the maxillæ, with their two-jointed palpi (*f*) at the base; *j*, the labium to which is appended the ligula (*i g*); below are the labial palpi; *h*, the two basal joints; *k*, compound eyes.

The gall-flies (Fig. 362, *Cynips*) are small Hymenoptera which lay eggs in the leaves or stems of the oak, etc., which, from the irritation set up by their presence, causes the deformation termed a gall.

The ichneumon-flies (Fig. 363) are very numerous in species and individuals; by their ovipositor, often very long, they pierce the bodies of caterpillars, inserting several or many eggs into them; the larvæ develop feeding only on the fatty tissues of their host, but this usually causes the death of the caterpillar before its transformation. Certain minute species, with veinless wings (Fig. 364, *Platygaster*), of the canker-worm eggs, are egg-parasites, ovipositing in the eggs of butterflies, dragon-flies, etc.

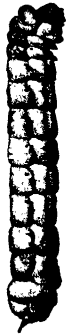


Fig. 360.—Horn-tail: larva of *Tremex columba*. Nat. size.

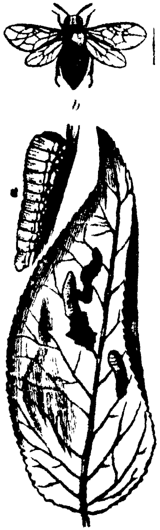


Fig. 361.—Pear Slug. natural size, gnawing leaves. *a*, larva enlarged; *b*, the fly.

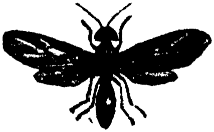


Fig. 362.—Gall-fly of oak.

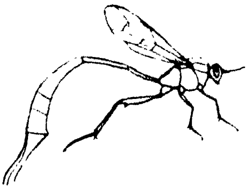


Fig. 363.—An Ichneumon-fly.

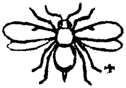


Fig. 364.—Egg parasite of Canker-worm. Highly magnified.

The family of ants is remarkable for the differentiation of the species and the consequent complexity of the colony, the division of labor and the reasoning powers manifested by the workers and soldiers, which, with the males and females, constitute the ant-colony.

Certain ants enslave other species; have herds of cattle, the aphides; build complicated nests or formicaries (Fig.), tunnel broad rivers, lay up seeds for use in the winter-time, are patterns of industry, and exhibit a readiness in overcoming extraordinary emergencies, which show that they have sufficient reasoning powers to meet the exigencies of their life; their ordinary acts being instinctive—namely, the results of inherited habits. The leaf-cutter ants of Central and South America (Fig. 365) are famous from

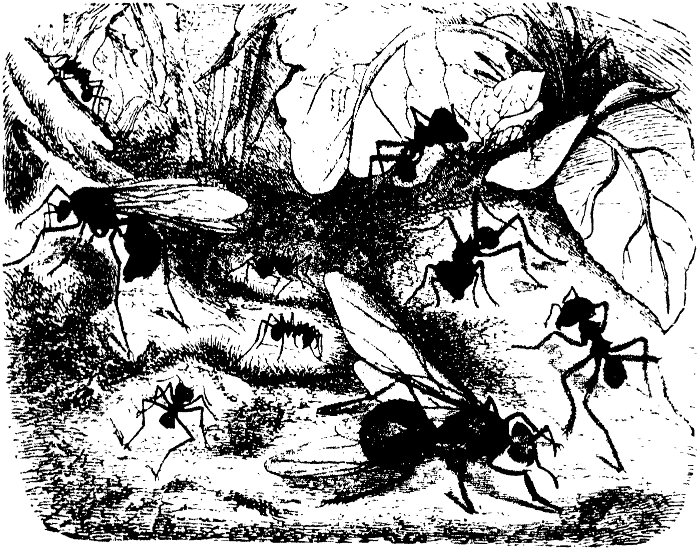


Fig. 365.—Œcodoma, or Leaf-cutter Ant of Nicaragua.—After Belt.

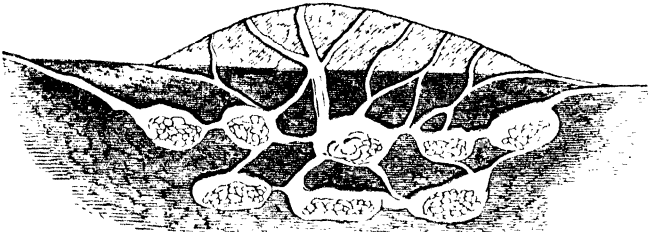


Fig. 366.—Diagram of an ant's nest (Œcodoma), the chambers below containing the ant food.—After Belt.

their leaf-cutting habits; the soldiers have large triangular heads, while the workers have much smaller rounded heads. Fig. 367 represents a species of *Eciton*.

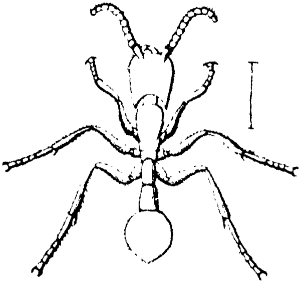


Fig. 367. Eciton

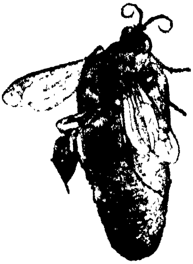


Fig. 368. Mud-dauber

The mud-daubers (*Pelopæus*, Fig. 368) build their nests against stone walls, of pellets of mud, while the sand- and mud-wasps dig deep holes (Fig. 369, *Sphex ich*

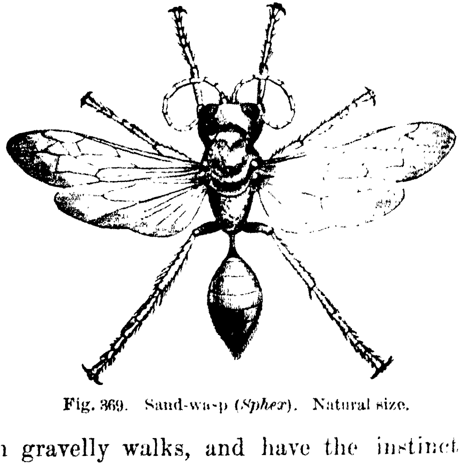


Fig. 369. Sand-wasp (*Sphex*). Natural size.

Linn.) in gravelly walks, and have the instinct to sting grasshoppers in one of the thoracic ganglia, thus paralyzing the victim, in which the wasp lays her eggs; the young hatching, feed upon the living but paralyzed grasshoppers, the store of living food not being exhausted until the larval wasp is ready to stop eating and finish its transformations.

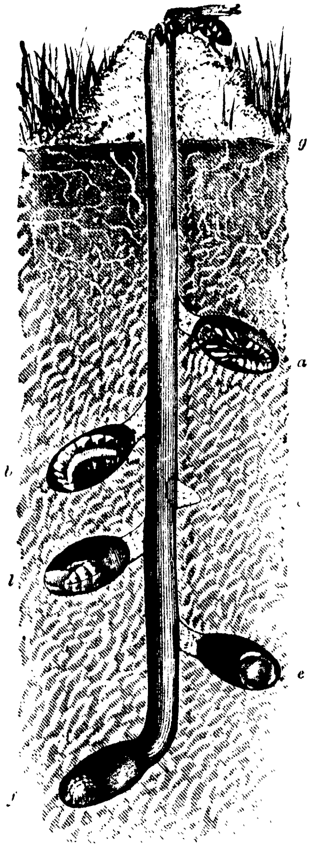


Fig. 370.—Nest of Andrena. *g*, level of ground; *a*, first-made cell, containing a pupa; *b*, *l*, larvæ; *e*, pollen mass with an egg laid on it; *f*, pollen mass freshly deposited by the bee.—Emerton *del.*

The genuine paper-making wasps are numerous in species; here the workers are winged, and only differ from the females or queens in being rather smaller and with undeveloped ovaries. The series of genera from *Odynerus,* which builds cells of mud, and in which there are no workers, up to those which have workers and build paper cells, such as *Polistes,* is quite continuous. The genuine paper-making wasps, such as *Vespa,* build several tiers of cells, arranged mouth downward, and enveloped by a wall of several thicknesses of paper. In the *Vespæ,* the females found the colony, and raise a brood of workers, which early in the summer assist the queen in completing the nest.

The bees also present a gradual series from those which are solitary, living in holes in the earth, like the ants (Fig. 370, nest of *Andrena vicina* Smith), and forming silk-lined earthen cocoons, to those which are social, with winged workers, slightly differing from the queens. The queen humble-bee hybernates, and in the spring founds her colony by laying up pellets of pollen in some subterranean mouse-nest or in a stump, and the young hatching, gradually eat the pollen, and when it is exhausted and they are fully fed, they spin an oval cylindrical cocoon; the first brood are workers, the second males and females. The partly hexagonal cells of the stingless bees of the tropics (*Melipona*) are built by the bees, while the hexagonal cells of the honey-bee are made by the bees from wax secreted by minute subcutaneous glands in the abdomen. Though the cells are hexagonal, they are not built with mathematical exactitude, the sides not always being of the same length and thickness.

The cells made for the young or larval drones are larger than those of the workers, and the single queen cell is large and irregularly slipper-shaped. Drone eggs are supposed by Dzierzon and Siebold not to be fertilized, and that the queen bee is the only animal which can produce either sex at will. Certain worker-eggs have been known to transform into queen bees. On the other hand, worker-bees may lay drone eggs. The maximum longevity of a worker is eight months, while some queens have been known to live five years. The latter will often, under favorable circumstances, lay from 2000 to 3000 eggs a day. The first brood of workers live about six weeks in summer, and are succeeded by a second brood.

CLASS II.—INSECTA.

A distinct head, thorax, and abdomen; breathing by tracheæ; usually with a metamorphosis.

SUB-CLASS I. *Malacopoda.*—Numerous simple spiracular openings with isolated tracheal twigs; nervous system with an incomplete chain of minute ganglia, but the cords widely separated (Peripatus).

SUB-CLASS II. *Myriopoda.*—Thorax and abdomen forming a continuous region, with from six to two hundred joints, each bearing a pair of genuine legs.

Order 1. *Chilognatha.*—Body cylindrical or flattened, with no sternum; a distinct metamorphosis (Julus, Polydesmus).

Order 2. *Pauropoda.*—Microscopic; body of six to nine segments besides the head (Pauropus).

Order 3. *Chilopoda.*—Sternum large, body flattened (Scolopendra, Lithobius).

SUB-CLASS III. *Arachnida.*—Head and thorax intimately united; no antennæ, and only one pair of maxillæ; no genuine abdominal legs.

Order 1. *Acarina.*—No thorax separate from the abdomen (Acarus, Ixodes).

Order 2. *Pedipalpi.*—Maxillary palpi often ending in a forceps or claw; abdomen distinctly segmented (Scorpio, Chelifer, Phalangium).

Order 3. *Araneina.*—Abdomen rounded, bearing two or three pairs of spinnerets, and attached by a slender pedicel to the thorax; no metamorphosis (Epeira, Mygale).

SUB-CLASS IV. *Hexapoda.*—Antennæ always present, and two pairs of maxillæ; six thoracic legs; a genuine metamorphosis.

Order 1. *Thysanura.*—Wingless, minute, with a spring, or abdomen ending in a pair of caudal stylets; usually no compound eyes; no metamorphosis (Podura, Campodea, Lepisma).

Order 2. *Neuroptera.*—Winged, net-veined, of equal size, pupa often active; abdomen often long and slender (Ephemera, Libellula, Phryganea, Chrysopa, Perla, Termes).

Order 3. *Orthoptera* —Wings net-veined; fore-wings narrow, straight, not often used in flight; metamorphosis incomplete; pupa active (Forficula, Locusta, Caloptenus, Phaneroptera, Acheta).

Order 4. *Hemiptera.*—Mouth-parts forming a sucking beak; prothorax usually large; fore-wings often thickened at base; pupa active (Coreus, Arma, Pentatoma, Cicada, Coccus, Aphis).

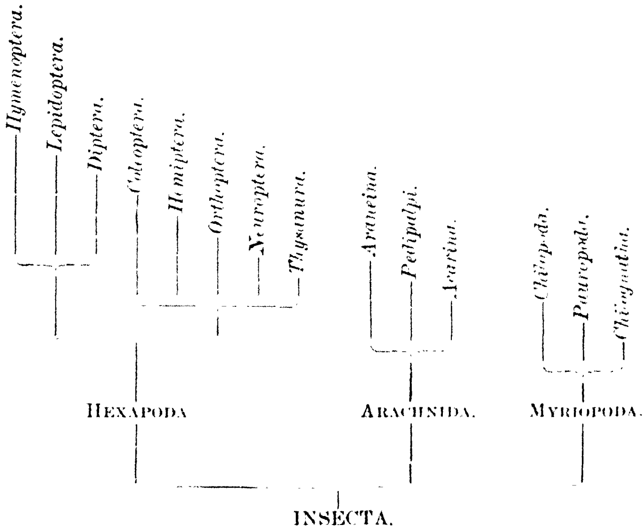
Order 5. *Coleoptera.* —Fore-wings thick, ensheathing the hinder pair, which are alone used in flight; mouth-parts free, adapted for biting; metamorphosis complete (Doryphora, Clytus, Lucanus, Harpalus, Cicindela),

Order 6. *Diptera.* — Only two wings; mouth-parts adapted for lapping and sucking; a complete metamorphosis (Musca, Œstrus, Syrphus, Cecidomyia, Tipula, Culex).

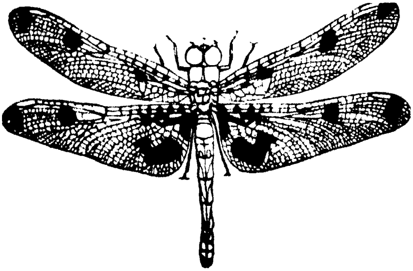
Order 7. *Lepidoptera.*—Body and wings covered with scales; maxillæ lengthened into a very long tongue; larvæ (caterpillars) with abdominal legs (Tinea, Geometra, Noctua, Bombyx, Sphinx, Papilio).

Order 8. *Hymenoptera.*—Wings clear, with few veins; mouth-parts with a variety of functions, *i.e.*, biting, lapping liquids, etc. In the higher families the thorax consists of four segments, the first abdominal segment of the larva being transferred to the thorax in the pupa and imago. Metamorphosis complete. (Tenthredo, Cynips, Ichneumon, Sphex, Vespa, Apis.)

TABULAR VIEW OF THE SUB-CLASSES AND ORDERS OF INSECTA.



Laboratory Work.—In dissecting Myriopods, spiders and insects, the dorsal portion of the integument should be carefully removed with fine scissors, leaving the hypodermis untouched; this should then be raised, disclosing the delicate heart or dorsal vessel. The alimentary canal will be found passing through the middle of the body; it should be laid open with the scissors, or better, a hardened alcoholic specimen can readily be cut in two longitudinally, and if the section is true, the œsophagus and crop—for example, of a locust—can be laid open, and the rows of teeth examined. The thoracic and abdominal portions of the nervous system, which lies loosely on the floor of the body, can be readily found by raising the alimentary canal; but the brain and infra-œsophageal ganglia can best be detected by a longitudinal section of the head. The ovaries always lie above the intestine, and the two oviducts unite below the nervous cord to form the common duct which opens on the ventral side of the third segment in front of the anus, which is situated dorsally. Insects should be dissected in a shallow pan lined with wax or cork, and the parts floated out; fresh specimens are desirable. The body may also be dissected, each segment with its appendages being separated and glued in their true sequence to a card. By simply dissecting an insect in this way, the student will acquire a valuable knowledge of the external structure of insects.



Dragon-fly (*Diplax Elisa*).

CHAPTER VIII.

BRANCH VIII.—VERTEBRATA.

General Characters of Vertebrates.—The fundamental characters of the Vertebrates are not the possession of a segmented vertebral column, enclosing a nervous cord and a skull, and containing a genuine brain, for these features, though common to most Vertebrates, are wanting in the lancelet (*Amphioxus*) and in a degree in the hag-fish, and even the lamprey; but the essential character is the division of the body-cavity by the notochord (in the lancelet, etc.), or by the back-bone of higher Vertebrates into two subordinate cavities, the upper (neural) containing the nervous cord, and the lower (enteric) the digestive canal and its appendages and the heart. These are the only characters which will apply to every known Vertebrate animal (compare p. 226 with Figs. 371, 375 and 376.)

In general, however, the Vertebrates are distinguished from the members of the other branches by the following characters: they are bilaterally symmetrical animals, with a dorsal and ventral surface, a head connected by a neck with the trunk; with two eyes and two ears, and two nasal openings, always occupying the same relative position in the head; an internal cartilaginous or bony, segmented skeleton, consisting of vertebræ, from the bodies of which are sent off dorsal processes which unite to form a cavity for a spinal cord, the latter sending off spinal nerves in pairs * corresponding to the segmentations (vertebræ) of the spinal column.

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* Except in Amphioxus, in which the spinal nerves arise right and left *alternately*.

From the underside of the vertebræ are sent off processes articulating with the ribs, which enclose the digestive and central circulatory organs. There is a skull formed by a continuation of the vertebral column, enclosing a genuine brain, consisting of several pairs of ganglia. To the vertebral column are appended two pairs of limbs, supported by rays irregularly repeated, or a series of bones of a definite number, attached to the vertebral column by a series of bones called respectively the shoulder and pelvic girdle.

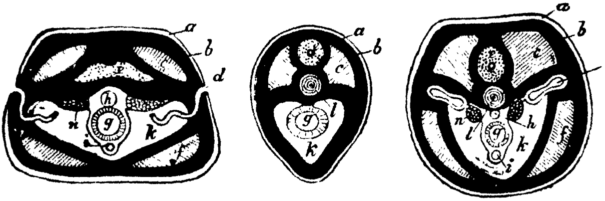

Fig 371.—Transverse section of a worm, of Amphioxus, and of a Vertebrate contrasted. *a*, outer or skin layer; *b*, dermal connective layer; *c*, muscles; *d*, segmental organ: *h*, arterial, and *i*, venous blood-vessel; *g* intestine: *l*, notochord.—After Haeckel.

It will be observed that the fact of segmentation, so prominent a feature in the Worms and Arthropods, survives, or at least reappears in a marked degree in the Vertebrates, as seen not only in the vertebral column, but in the arrangement of the spinal nerves. It is perceived also in the arrangement of the muscles into masses corresponding to the vertebræ; and in the segmental organs or tubes forming the kidneys of the sharks and rays, while segmentation is especially marked in the disposition of the primitive vertebræ of the early embryos of all Vertebrates.

The digestive canal consists of a mouth with lips or jaws, armed with teeth, a pharynx leading to the lungs; an œsophagus and thyroid gland; sometimes a crop (ingluvies), often a fore-stomach (proventriculus); a stomach and intestine, cloaca and vent. Into the beginning of the intestine passes a duct leading from a large liver; a gall-bladder, usually a pancreas, and a spleen, also communicating with the intestine. The products of digestion do not all pass through the walls of the stomach and directly enter the circulation, as in the invertebrates, but there is a system of intermediate vessels called the lacteal system or absorbents, which take up a part of the chyle from the digestive organs and convey it to the blood-vessels.

There is a true heart, with one, generally two, auricles, and one or two ventricles with thick, muscular walls, and besides arteries and veins, a capillary system, *i. e.*, minute vessels connecting the ends of the smaller arteries with the smaller veins. There are no genuine capillaries in the lower animals exactly comparable with those of the Vertebrates.

The blood is red in all the Vertebrates except the lancelet, and contains two sorts of corpuscles, the white corpuscles like the blood-corpuscles of invertebrates, and red corpuscles not found in invertebrates, and which are said by some authors to be derived from the white corpuscles.

While fishes and larval Amphibians breathe by gills, all land and amphibious Vertebrates breathe the air directly by means of cellular sacs called lungs, and connected by a trachea with the pharynx, the trachea being situated beneath the œsophagus, and the opening from the mouth into the pharynx leading into the trachea being placed below the throat or passage to the œsophagus. The air filling the cells or cavities of the lungs passes by osmose through the walls of the cells into the blood sent by the heart through the pulmonary artery, and after being oxygenated it returns by the pulmonary vein to the heart. On the other hand, carbonic acid passes from the blood out of the lungs through the trachea.

The nervous system of Vertebrates consists of a brain and spinal cord. The brain consists of four pairs of lobes, *i. e.*, the olfactory lobes, cerebral hemispheres, the optic thalami (Thalamencephalon) and pineal gland, and the optic lobes; and two single divisions: the cerebellum and the beginning of the spinal cord, called the *medulla oblongata*. The olfactory lobes are the most anterior, and send off the nerves of smell to the nose. The cerebral hemispheres in the fishes and amphibians are little larger than the adjoining lobes, but in the reptiles become larger, until in the mammals, and especially in the apes and man, they fill the greater part of the brain-box and overlap the cerebellum; the latter, in the mammals, also exceeding all the other lobes in size, excepting the cerebrum.

Attached to a downward prolongation (infundibulum) of the optic thalami is the curious pituitary body. The medulla sends nerves to the skin and muscles, giving sensibility and motion to the face, eyes and nose, to the larynx and sensitive portion of the lungs; a pair also is sent to the lungs and heart. If the spinal marrow is severed, the parts below are paralyzed; if the medulla is cut or broken up mammals die at once, while the lower Vertebrata die sooner or later. The brain in an embryo originally consists of three vesicles or primitive lobes; and the correspondence between

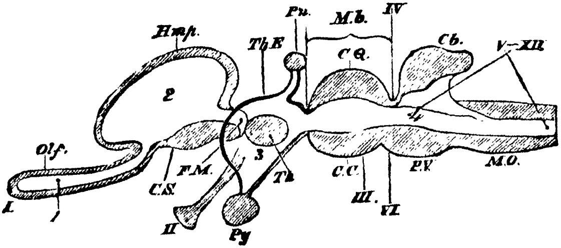

Fig. 372.—Diagrammatic, longitudinal and vertical section of a Vertebrate brain. *Mb*, mid brain; what lies in front of this is the fore brain, and what lies behind, the hind brain. *L*, lamina terminalis; *Olf*, olfactory lobes; *Hmp*, cerebral hemispheres; *Th E*, thalamencephalon; *Pn*, pineal gland; *Py*, pituitary body; *FM*, foramen of Munro; *CS*, corpus striatum; *Th*, optic thalamus; *CQ*, corpora quadrigemina; *CC*, crura cerebri; *Cb*, cerebellum; *PV*, pons varolii; *MO*, medulla oblongata; *I*, olfactorii; *II*, optici; *III*, point of exit from the brain of the Motores oculorum; *IV*, of the pathetici; *VI*, of the abducentes; *V-XII*, origin of the other cerebral nerves; 1, olfactory ventricle; 2, lateral ventricle; 3, third ventricle; 4, fourth ventricle.—After Huxley.

the three primitive lobes, called respectively the fore, mid, and hind brain, may be seen by the following table:

TABULAR VIEW OF THE SUBDIVISIONS OF THE VERTEBRATE BRAIN.

Fore brain.	Olfactory lobes or ganglia, with their ventricles (rhinencephalon).
	Cerebrum or cerebral lobes or hemispheres (with the two lateral or first and second ventricles, forming the prosencephalon or prothalami).
	Optic thalami, with the third ventricle and conarium above and hypophysis below (Thalamencephalon; pineal gland).

Mid brain.	Optic lobes, corpora bigemina or quadrigemina (mesencephalon). Crura cerebri. Optic ventricle or Iter a tertio ad quartum ventriculum.
Hind brain.	Cerebellum (with its ventricle and the pons varolii, forming the metencephalon). Medulla oblongata and fourth ventricle.

The accompanying sketches represent the typical nervous system of an amphibian, which also resembles that of many fishes, and even the lower *Reptilia*.

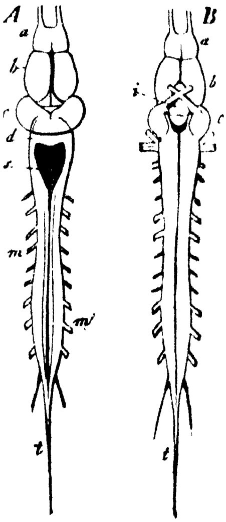

Fig. 373.—Brain and spinal cord of the frog. *A*, from above. *B*, from below. *a*, olfactory lobes; *b*, cerebral hemispheres; *c*, optic lobes; *d*, cerebellum in the form of a lamella bridging over the fourth ventricle (*s*); *m*, spinal cord; *t*, terminal cord.—After Gegenbaur.

The spinal cord (Fig. 374) usually extends through the whole length of the spinal canal, except in the toads and frogs, birds and many mammals, where it stops short of the end of its canal. In those Vertebrates with limbs, the cord enlarges where the nerves which supply them are sent off; these are the cervical or thoracic, and lumbar enlargements, especially large in turtles and birds. The white and gray substance of the brain continues in the cord.

As the most essential characteristic of Vertebrates is the internal skeleton (endoskeleton) we will enter more into detail in describing it, and afterwards notice the external skeleton (exoskeleton).

In the embryos of higher Vertebrates and in the adult lancelet, hag-fish and lamprey, the vertebral column is represented by a rod-like axis (*notochord* or *chorda dorsalis*) which is composed of indifferent, or only partly organized cells, the substance of the chord resembling cartilage. These chordal cells secrete a membrane called the *chordal sheath*. The notochord is not segmented. In all Vertebrates above the lamprey, the vertebral column grows around the notochord, which finally

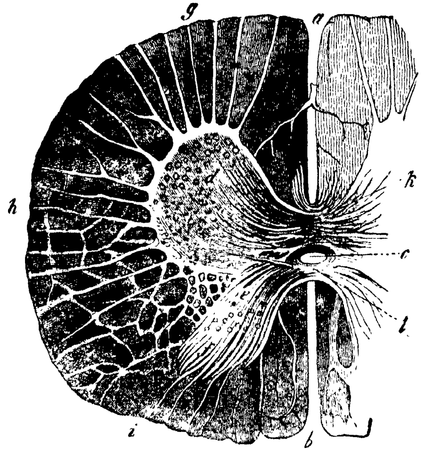

FIG. 374.

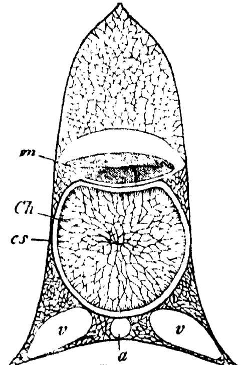

FIG. 375.

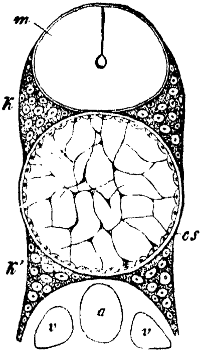

FIG. 376.

Fig. 374.—Transverse section through the spinal cord of a calf. *a*, anterior, *b*, posterior longitudinal fissure; *c*, central canal; *d*, anterior, *e*, posterior cornua; *f*, substantia gelatinosa; *g*, anterior column of the white substance; *h*, lateral, *i*, posterior column; *k*, transverse commissures.—After Gegenbaur.

Fig. 375.—Section through the vertebral column of Ammocœtes (lamprey). *Ch*, notochord; *cs*, chordal sheath; *m*, spinal chord; *a*, aorta; *v*, veins.

Fig. 376.—Section through the spinal column of a young salmon. *Ch*, notochord; *cs*, chordal sheath; *m*, spinal chord; *k*, superior, *k'*, inferior arch (rudimentary); *a*, aorta; *v*, veins.—After Gegenbaur.

forms the central portion of the bodies of the vertebræ, and in the higher Vertebrates is wholly effaced; the centra or bodies of each vertebra of a lizard, bird or mammal being solid bone. Figs. 375 and 376 represent the relations of the notochord in an adult lamprey and a young fish.

The vertebra of a bony fish or higher vertebrate consists of a *body*, with a dorsal or neural spine; a pair of *oblique processes* (zygapophyses) arching over and enclosing the spinal cord; and *transverse processes*, bending downwards, to which the *ribs* are articulated; certain of the thoracic ribs uniting with the *sternum* or breast-bone (Figs. 377 and 378.)

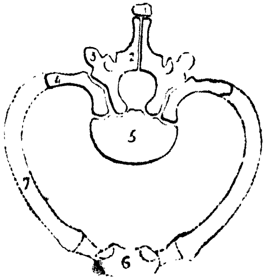

Fig. 377.—Diagram of a Vertebra with its body (5), rib (7), breast bone (6); 1, neural spine; 2, 3, fore and hind oblique processes; 4, transverse processes.

Vertebræ like those of fishes, which are hollow or concave at each end, are said to be *amphicœlous;* those hollow in front and convex behind *procœlous*, as in most toads and frogs and crocodiles, and most existing lizards, and those convex in front and concave behind *opisthocœlous*, as in the garpike, some Amphibians (the salamanders and certain toads, *Pipa* and *Bombinator*).

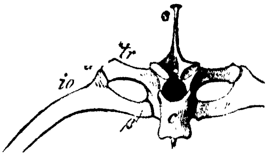

Fig. 378.—Thoracic vertebra of buzzard (Buteo vulgaris). *c*, centrum or body; *s*, superior spinous process; *tr*, transverse process; *io*, rib: *a*, tuberculum of the rib · *β*, capitulum of the rib.—After Gegenbaur.

Vertebrates never have more than two pairs of limbs, an anterior and hinder pair; the pectoral pair of fins of fishes represent the fore limbs of Amphibians and higher Vertebrates, and the arms of man; the two ventral fins represent the hind legs of higher Vertebrates, and the legs of man. Each pair of limbs is connected by ligaments and muscles to a girdle or set of bones, called respectively the shoulder girdle and pelvic girdle, each girdle being connected by muscles to the vertebral column. The shoulder girdle consists of a *clavicle* (or collar-bone), *scapula* (or shoulder-blade), and *coracoid* bone, usually a process of the scapula. These bones differ greatly in the different classes, and are reduced to cartilaginous pieces in sharks. The pelvic girdle, or *pelvis,* consists of three bones, *i.e.,* one dorsal, the *ilium,* and two ventral, the anterior of which is called *pubis,* and the posterior *ischium.*

The limbs each consist of a single long bone, succeeded by two long bones, followed by two transverse rows of short wrist or ankle bones, and five series of long finger or toe bones, called phalanges. For example, in the fore limb of most Vertebrates, as in the arm of man, to the shoulder girdle, *i.e.,* at the point of junction of the three bones composing it, is articulated the *humerus;* this is succeeded by the *ulna* and *radius,* the wrist-bones or carpals, and the finger-bones or *phalanges,* the single row of phalanges forming a *digit* (finger or toe). To the point of union (*acetabulum,* Fig. 381, *a*) of the three pelvic bones is articulated the *femur,* or thigh; this is succeeded by the *tibia* and *fibula* (shank-bones), the tarsal and metatarsal bones (ankle-bones), and the phalanges or bones forming the digits (toes).

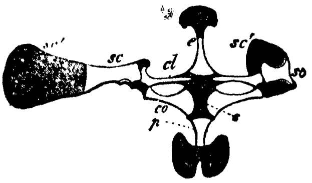

FIG. 379.

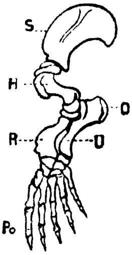

FIG 380.

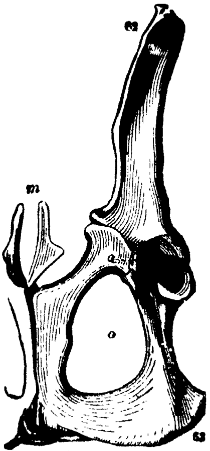

FIG. 381.

Fig. 379.—Sternum and shoulder girdle of Frog (*Rana temporaria*). *p,* body of the sternum; *sc,* scapula; *sc',* supra-scapula; *co,* coracoid bone, fused in the middle line with its fellow of the opposite side (*s*); *cl,* clavicle; *e,* episternum. The extreme shaded double portion below *p* is the xiphisternum. The cartilaginous parts are shaded.—After Gegenbaur.

Fig. 380.—Fore-leg of a seal. *S,* scapula; *H,* humerus; *O,* olecranon or tip of elbow; *R,* radius; *U,* ulna; *Po,* pollex, or thumb.

Fig. 381.—Pelvis or pelvic bones on one side of a marsupial (**Kangaroo**). 62, ilium; *a,* situated on the pubic bone (*pubis*) indicates the acetabulum or concavity for the articulation of the head of the femur; 63, ischium, consolidated with the pubis. The three bones thus consolidated form the **os innominatum;** *m,* **marsupial** bones articulated to the pubic bones.—After Owen.

Figs. 383–385 represent the simplest form of the posterior limbs in the higher Vertebrates, that of the bird showing an extreme modification in form. At first all limbs arise as little pads, in which the skeletons subsequently develop, and in early life the limbs of all Vertebrates above the fishes are much alike, the modifications taking place shortly before birth. According to Gegenbaur and others, the limbs of Vertebrates have been probably derived from the pectoral and ventral fins of fishes in which the fin-rays are irrelatively repeated.*

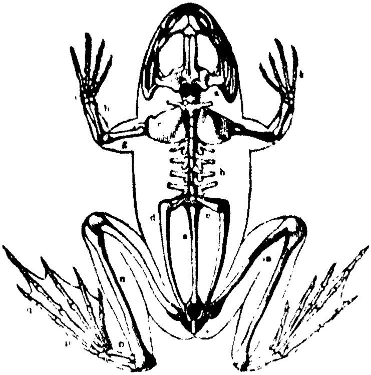

Fig. 382.—*a*, skull; *b*, vertebræ; *c*, sacrum, and *e*, its continuation (urostyle); *f*, suprascapula; *g*, humerus; *h*, fore-arm bones; *i*, wrist bones (carpals and metacarpals); *d*, ilium; *m*, thigh (femur); *n*, leg bone (ulna): *o*, elongated first pair of ankle-bones (tarsals); *p*, *q*, foot bones or phalanges.—After Owen.

In the fins of fishes there is a simple system of leverage; in the limbs of higher air-breathing Vertebrates, formed by walking on land, a compound system of leverage (Wyman).

The head of all Vertebrates above the lancelet is supported by a more or less perfect cartilaginous or bone framework, the skull (cranium), or brain-box (Fig. 386). It is a continuation of the vertebral column, and protects the brain, besides forming the support of the jaws, tongue-bone (hyoid bone), and branchial arches. The series of lateral (visceral or branchial) arches varies, but there may be nine; the most anterior (if it be counted as the first one, Fig. 387, *a*, *b*, *c*) is formed by the labial cartilages (*trabeculæ cranii*); next comes the mandibular arch (*o*, *n*), which is succeeded by the hyoid arch (II.) and the six branchial arches. In the embryos of all Vertebrates these visceral arches are well marked; of the slits or openings between them, the first is destined to form the mouth, the next pair of slits

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* A modified form of this theory is advocated by Balfour and J. K. Thatcher, who attempt to show that the limbs with their girdles were derived from a series of similar simple parallel rays, and that they were originally a specialization of the continuous lateral folds or fins of embryo fishes, and probably homologous with the lateral folds of the adult lancelet (Amphioxus).

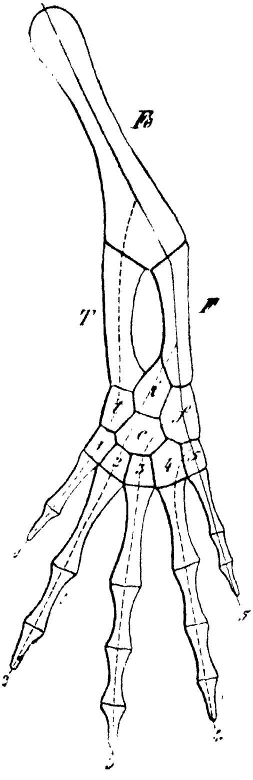

FIG. 383.

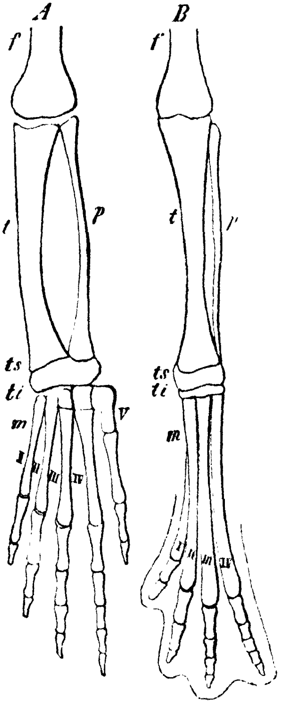

FIG. 384.

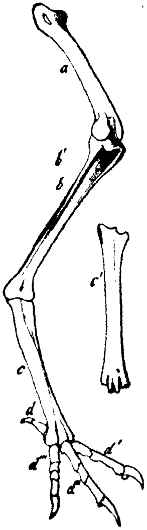

FIG. 385.

Fig. 383.—Hind leg of a larval Salamander. The dotted lines are drawn through the rays to which the different pieces belong. *Fe*, femur; *T*, tibia; *F*, fibula; *i*, *t*, *c*, *f*, tarsal bones; *i*, os intermedium; *t*, tibiale; *f*, fibulare; *c*, centrale; 1-5, the five tarsals. The first row of phalanges are called metatarsals (in the hand, metacarpals).

Fig. 384.—Bones of the foot of a Reptile (lizard) *A*, and an embryo bird, *B*. *f*, femur; *t*, tibia; *n*, fibula; *ts*, upper, *ti*, lower pieces of the tarsus; *m*, metatarsus; *I-V*, metatarsalia of the toes.

Fig. 385.—Leg of the Buzzard (*Buteo vulgaris*). *a*, femur; *b*, tibia; *b'*, fibula; *c*, tarso-metatarsus; *c'*, the same piece isolated, and seen from in front; *dd'*, *d''*, *d'''*, the four digits or toes.—After Gegenbaur.

in the Amphibia and higher Vertebrates forms the ear-passage, while the other slits may remain open in fishes, forming gill-slits or spiracles, but are closed in the higher Vertebrates. As a rule, the skull is symmetrical, exceptions being found in the flounders and the bones about the nose of certain whales and porpoises. The base of the skull is perforated for the exit of the nerves proceeding from the base of the brain, and the hinder bone (*occiput*) is perforated (*foramen magnum*) for the passage of the spinal cord from the medulla oblongata.

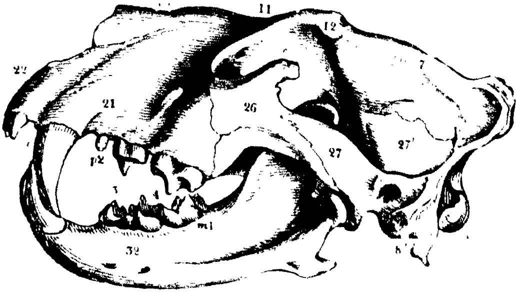

Fig. 386.—Skull of the Lion 2, occipital condyle ; 7, Parietal bone and sagittal crest ; 8, parocipital ; 27′, squamosal bone ; 27, zygomatic arch ; 26, malar bone ; 11, frontal bone ; 12, post-orbital process ; 15, nasal bone ; 21, maxillary bone ; 22, premaxillary bone ; 32, mandible ; 3, occipital crest ; *c*, canine teeth ; p^2, second premolar ; *ml*, molar tooth.—After Owen.

It is probable that there is a general parellelism between the head of Insects and Vertebrates, *i.e.*, that while the head of insects, for example, consists of a certain number of segments, homologous with those of the rest of the body, and with mouth-parts homologous with the limbs ; that the skull is also segmented, and an expansion and continuation of the vertebral column. Gegenbaur even maintains that the various arches of the head are homologous with the limbs.

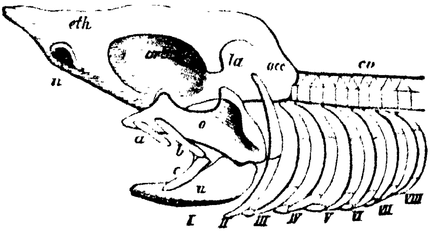

Fig. 387.—Skull and visceral skeleton of a *Selachia* (diagram). *occ*, occipital region ; *la*, wall of the labyrinth ; *eth*, ethmoidal region ; *n*, nasal pit ; *a*, first, *b*, *c*, second labial cartilage ; *o*, superior, *n*, inferior portion of the mandibular arch *I.* ; *II.*, hyoid arch ; *III.* *VIII.* (1-6), branchial arches.—After Gegenbaur.

On the other hand, while the brain of insects is a single pair of ganglia like those of the rest of the body, the different ganglia forming the brain of Vertebrates are concentrated in the head alone; still the different pairs of nerves sent off from the base of the brain are homologous with the spinal nerves, sent off at intervals corresponding to each vertebra.

There are two theories of the composition of the skull. That of Oken, Goethe, and of Owen, who believed that the skulls of the bony fishes and mammals were composed of three or four segments. It should be noticed that these views are based on an examination of highly specialized vertebrates. From a study, however, of the more generalized types of fishes (such as the sharks), and the embryos of vertebrates belonging to different groups, the old vertebrate theory of the skull has been discarded, and the view of Gegenbaur, confirmed by Salensky, is probably nearly the correct one. As stated by Gegenbaur:

1. The skull is comparable to a portion of the vertebral column, which contains at least as many vertebral segments as there are branchial arches. This view is borne out by the following facts:

   a. The notochord, which forms the foundation of the vertebral column, passes through the cranium in the same way as it passes through the vertebral column.

   b. All the nerves which pass out of the base of the skull (or that portion traversed by the notochord) are homologous with the spinal nerves.

   c. The difference between the skull and vertebral column consist of secondary adaptations to certain conditions, which are external to the skull, and are partly due to the development of a brain.

2. The skull may be divided into two regions, a *vertebral* portion and an anterior *evertebral* portion, lying beyond the end of the notochord.

3. The number of vertebræ which enter into the formation of the skull are nine at least (according to Salensky, in the sturgeon, seven); the exact number is immaterial.

In the lancelet there is no skull, or even the rudiments of one (unless the semi-cartilaginous supports of the tentacles be regarded as such), hence the Vertebrates are divided into the skulless or *acraniate* (*Acrania*, represented by the lancelet alone) and the skulled or *craniate* (*Craniota*), the latter series comprising all forms from the hag-fish to man. In the Craniota the skulls may be, according to Gegenbaur, divided into two groups. In the hag and lamprey the notochord is continued into the base of a small cartilaginous capsule, enclosing the brain, and which represents the skull of higher Vertebrates (Craniota). This capsule behind is continuous with the spinal column.

With the skull of the second form two jaws are developed, hence all the vertebrates above the hag and lamprey form a series (*Gnathostomata*) opposed to the former, or *Cyclostomata*.

In the *Gnathostomata* there is a gradual modification and perfection of the skull. In the sharks it may be quite simple and cartilaginous; in the bony fishes it is highly specialized, consisting of a large number of separate bones. In the Amphibians we first meet with a skull consisting of few bones, easily comparable with those of mammals; in the reptiles and birds the ear-bones are external, forming the large quadrate-bone by which the lower jaw is articulated to the skull. A progress is seen in the mammals where the quadrate-bone becomes internal—one of the ear-bones (the *incus*). Now also, the brain becoming much larger, evincing a much higher grade of intellect, the skull is greatly enlarged to accommodate the great increase in size of the cerebrum and cerebellum, the perceptive and reasoning faculties predominating over those regions of the brain and skull devoted to perceiving, grasping, and masticating the food.

Though not properly forming part of the skeleton or developed with it, we may here consider the teeth.

The teeth of Vertebrates are formed from the modified epidermis and cutis, or dermis; the former secretes the enamel and the latter is changed into the pulp or dentine. The simplest form of tooth is conical. In the jawless hag there are no teeth in the lips, but a single median tooth on the palate and two rows of comb-like teeth on the tongue. In the lamprey the edges of the circular mouth are provided with circular rows of conical horny teeth. The teeth of higher Vertebrates are derived from the cells of the mucous membrane of the mouth, which is formed of connective tissue as well as epithelium. The teeth of fishes are developed not only in one or several rows in the lip, but may also arm the bony projections into the mouth-cavity of the palate, vomer and parasphenoid bones and the hyoid and branchial arches. In the Amphibia teeth survive on the palatine and vomerine bones, more rarely on the parasphenoid ; among the reptiles, the snakes and lizards alone have teeth on the palatine and pterygoid bones, while in the crocodiles and in mammals the teeth are confined to the maxillary bones. In the geckos, snakes and the crocodiles, as well as the mammals, the teeth are inserted in sockets (alveoli) of the jaw. (Gegenbaur.)

In certain extinct birds (*Odontornithes*) there were teeth in the jaws, though all existing birds are toothless. It is said that rudimentary teeth were found by Geoffroy St. Hilaire in the jaws of a parrot. Blanchard afterwards found the germs of teeth there, though they never come through. In the Mammals the teeth are differentiated into incisors, canines, premolars and molars (Fig. 383). In descriptive anatomy the teeth are for convenience expressed by a formula, the number of teeth of the upper jaws being placed like the numerator of a fraction, and those of the lower jaw like the denominator, the initials of the names of the teeth being placed before the figures, thus the dental formula of man is $I\frac{2-2}{2-2}, C\frac{1-1}{1-1}; P\frac{2-2}{2-2}, M\frac{3-3}{3-3}$.

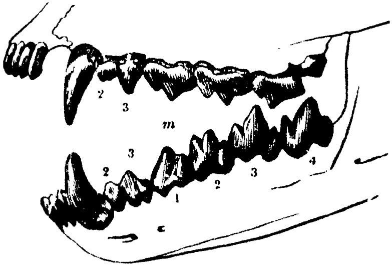

Fig. 383.—Teeth of the Tasmanian devil. The incisors are situated in front of the large conical canine teeth. 2, 3, premolars ; *m*, 1-4, four molar teeth.—After Owen.

In the fishes, Amphibians and reptiles, the worn-out teeth are replaced by a succession of new ones; in mammals (except cetaceans, where there is no change) there is but a single change, the first (milk) teeth being replaced by a second set of permanent teeth. The teeth of the lower Vertebrates are shed while swallowing the food. In the boa (Python) the teeth thus shed are found scattered along the intestinal canal and are discharged with the remnants of the food (Wyman).

The dermal or *exoskeleton* consists of the scales of fishes, reptiles and certain mammals, such as the armadillo, the feathers of birds and the hairs of mammals. Most scales arise from dermal papillæ (Fig. 384, *p*), and are covered over by a layer of enamel (Fig. 384, *o*) developed from the epidermis; so that the scales of sharks and rays, and turtles, arise from both the dermis and epidermis.

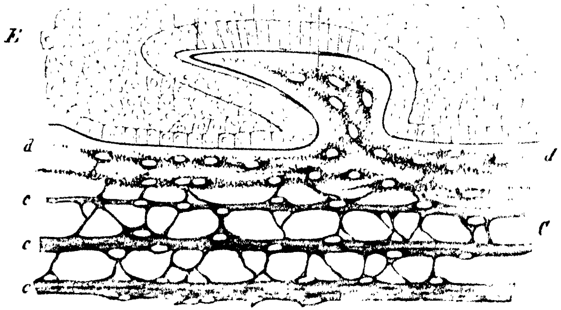

Fig. 384.—Vertical section through the skin of an embryonic shark. *C*, corium or dermis; *c*, *c*, *c*, layers of the corium; *d*, uppermost layer; *p*, papilla; *E*, epidermis; *e*, its layer of columnar cells; *o*, enamel layer.—After Gegenbaur.

A hair or feather is a modification of a scale; the papilla is sunken in a pit of the dermis, the conical cap of epidermis arising from it ultimately forming the hair or feather. The plates of turtles, the scales of snakes and lizards, and feathers of birds are epidermal. In the horns of mammals, as of the rhinoceros, and the hoofs of the horse, the epidermal substance is penetrated by numerous long dermal papillæ.

The head of the sturgeon, garpike, and of other ganoid fishes, is protected by solid dermal bones, and the shells of turtles are dermal structures.

The color of the skin of Vertebrates is due to pigment-granules situated either in the epidermis or dermis, and in the chameleon they are contained in special sacs (chromatophores) which are under the control of the nervous system.

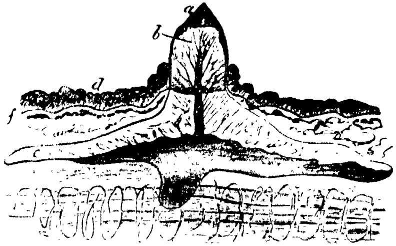

Fig. 385.—Placoid scale of dog-fish (vertical section magnified). *a*, enamel layer; *b*, dentine of the spine on the scale.—After Owen.

The muscular system of Vertebrates arises from the middle germ-layer (mesoderm), and in the germ the muscles in part arise from the primary segments indicated by the protovertebræ, while in the adults of fishes and certain salamanders, the muscular system is distinctly segmented, corresponding to the segmentation of the vertebral column, the four lateral trunk-muscles being divided into a number of segments by tendinous bands, which correspond in number to the vertebræ (Gegenbaur).

The eye in Vertebrates in its developmental history belongs to a different type of structure from that of any invertebrates, unless it be the larval Ascidians, for in both types the eye is said by Gegenbaur not to be directly developed from the ectoderm, but from the

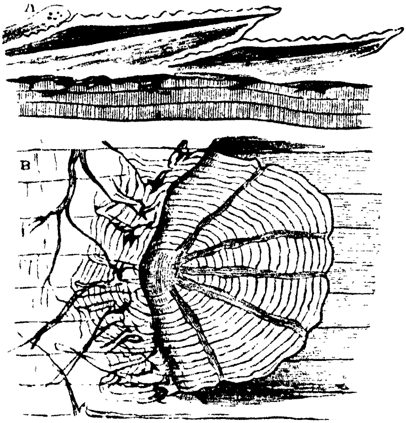

Fig. 386.—Cyloid scale of roach, magnified, seen i section, *A*, and from the surface, *B*.—After Owen.

anterior portion of the central nervous system. The difference between the highly-developed eye of a cuttle-fish and a bony fish, for example, consists in the fact that the rods and cones (similar to those of the invertebrate eye) forming a layer (the bacillar layer) behind the retina, are in the vertebrate eye turned away from, while in the invertebrates they are directed toward the opening of the eye.

The ear of Vertebrates is at first a primitive otocyst, or ear-vesicle, which is gradually cut off and enclosed, forming a cavity of the skull. As we rise towards the mammals, the ear becomes more and more developed until the inner, middle, and outer ear is formed ; the Eustachian tube being a modification of the first branchial cleft, forming the spiracle in the sharks (*Selachii*) and Ganoids.

In the lancelet a head is scarcely more set apart from the rest of the body than in many invertebrates. In the fishes and Amphibians the head is not separated by a neck from the trunk ; in reptiles the neck begins to mark off a head from the thorax, while in the birds and mammals the head is clearly demarked, the degrees of cephalization and transfer headward of those features subordinate to the intellectual wants of the animal becoming more striking as we ascend through the mammalian series to the apes, and finally man.

The development of Vertebrates can scarcely be epitomized in a few lines. The mode of growth of Amphioxus is a general expression for that of all Vertebrates, for all develop from fertilized eggs, which undergo total or partial segmentation of the yolk, become three-layered sacs and assume the peculiar vertebrate characters, the development of the mammals differing from that of the other classes only in comparatively unimportant features.

The Vertebrates are divided into two series or sub-branches: the *Acrania* and *Craniota* ; the former type is represented by but a single genus, order and class, the lancelet or *Amphioxus*. The sub-branch *Craniota* is divided into six classes, the Marsipobranchs, fishes, amphibians, reptilia, birds and mammals.

CLASS 1. LEPTOCARDII (*Lancelet*).

The lancelet is the only type of this class. From its worm-like form it was regarded as a worm by some authors, and as a mollusk ("Limax") by Pallas. The body is four or five centimetres in length, slender, compressed, pointed at each end, hence the generic name (*Amphioxus*, *αμφι*, both, *οξυς*, sharp), the head-end being thin, compressed. The muscular segments are distinct to the naked eye. From the mouth to the vent is a deep ventral furrow, and a slight fin extends along the back and ventrally as far front as the vent.

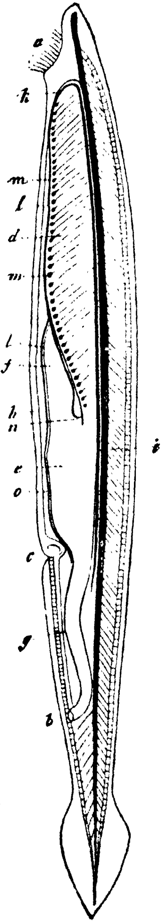

Fig. 387.—Lancelet (Amphioxus lanceolatus), magnified two and a half times. *a*, mouth, surrounded by cirri; *b*, anus; *c*, abdominal pore; *d*, branchial sac; *e*, gastric portion of the digestive canal; *f*, cæcum or liver; *g*, hind gut; *h*, cœlum or body-cavity; *i*, notochord, below which is the aorta, which accompanies it for nearly its whole length; *k*, aortic arches; *l*, aortic heart; *m*, enlargements of the branchial arteries; *n*, heart of the vena cava; *o*, heart of the portal vein.—After Quatrefages, from Gegenbaur.

The lancelet, *A. lanceolatus* (Pallas), lives in sand just below low-water mark, ranging on our coast from the mouth of Chesapeake Bay to Florida; it also occurs on the South American coast, and in the European seas and the East Indies, the species being nearly cosmopolitan.

As this is the lowest Vertebrate, its structure and mode of development merit careful study.

The mouth is oval, surrounded with a circle of ciliated tentacles supported by semi-cartilaginous processes arising from a circumoral ring. The mouth leads directly into a large broad pharynx or "branchial sac" (Fig. 387, *d*), protected at the entrance by a number of minute ciliated lobes.

The walls of this sac are perforated by long ciliated slits, comparable with those of the branchial sacs of Ascidians and of *Balanoglossus*. The water which enters the mouth passes out through these slits when it oxygenates the blood, and enters the general body-cavity, thence passing out of the body through the abdominal pore (Fig. 387, *c*). The pharynx leads to the stomach (*e*), with which is connected the liver or cæcum (*f*). There is a pulsatile vessel or tubular heart, beginning at the free end of the liver, and extending along the underside of the pharynx, sending branches to the sac and the two anterior branches to the dorsal aorta. "On the dorsal side of the pharynx the blood is poured by the two anterior trunks, and by the branchial veins which carry away the aërated blood from the branchial bars, into a great longitudinal trunk or dorsal aorta, by which it is distributed throughout the body." (Huxley.) There are also vessels distributed to the liver, and returning vessels, representing the portal and hepatic veins. The blood-corpuscles are white and nucleated.

The vertebral column is represented by a notochord which extends to the end of the head far in front of the nervous cord; and also by a series of small semi-cartilaginous bodies above the nervous system, and which are thought to represent either neural spines or fin-rays. The nervous cord lies over the notochord; it is not divided into a true brain* and spinal cord, but sends off a few nerves to the periphery, with nerves to the two minute eye-spots. There are no kidneys like those of the higher Vertebrates, but glandular bodies which may serve as such. The reproductive glands are square masses attached in a row on each side of the walls of the body-cavity. The eggs may pass out of the mouth or through the pore. Kowalevsky found the eggs issuing in May from the mouth of the female, and fertilized by spermatic particles likewise issuing from the mouth of the male. The eggs are very small, 0·105 millimetres in diameter. The eggs undergo total segmentation, leaving a segmentation-cavity which becomes the body-cavity.

The blastoderm now invaginates and the embryo swims about as a ciliated gastrula. The body is oval, and the germ does not differ much in appearance from a worm, starfish,

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*** Langerhans has figured an olfactory lobe; and all observers agree that a ventricle is present; thus there is a slight approximation to a brain.**

or ascidian in the same stage of growth. No vertebrate features are yet developed.

Soon the lively ciliated gastrula elongates, the alimentary tube arises from the primitive gastrula-cavity, while the edges of the flattened side of the body grow up as ridges which afterwards, as in all vertebrate embryos, grow over and enclose the spinal cord. When the germ is twenty-four hours old it assumes the form of a ciliated flattened cylinder, and now resembles an Ascidian embryo (Fig. 138, *B*), there being a nerve-cavity, with an external opening, which afterwards closes. The notochord appears at this time.

In the next stage observed the adult characters had appeared, the mouth is formed, the first pair of gill-openings are seen, eleven additional pairs appearing. It thus appears that while the lancelet at one time in its life presents Ascidian features, yet as Balfour states "all the modes of development found in the higher Vertebrates are to be looked upon as modifications of that of Amphioxus."

A second form of this group, from Moreton Bay, Northern Australia, has been described by Peters under the name of *Epigonichthys cultellus*. It differs from Amphioxus in the presence of a high dorsal fin, in the want of a distinct caudal and anal fin, with some differences in the structure of the mouth and oral tentacles. It is from thirteen to twenty-three millimetres in length.

CLASS I.—LEPTOCARDII.

Comprising the lowest Vertebrate known ; body lancet-shaped, with no skeleton ; notochord persistent, no brain ; no cranium ; no paired fins ; blood colorless ; a metamorphosis ; gastrula ciliated, free-swimming.

A single order (Pharyngobranchi), family (Amphioxini), and genus (Amphioxus), each with the characters of the class.

Laboratory Work.—The structure of the lancelet can only be imperfectly made out by a triplet lens and higher powers ; but by sections stained with carmine the anatomy can be well studied. Brooks has found the young in the later free-swimming stages on the surface of the ocean near Fortress Monroe.

CLASS II. MARSIPOBRANCHII (*Lampreys, or Cyclostomi*).

General Characters of the Cyclostomatous Vertebrates.—In the hag-fish and lamprey, representatives of the jawless Vertebrates, the body is long and slender, cylindrical, the skin smooth, scaleless, with only a median dorsal and ventral fin (or in *Myxine* only a small lower median fin); the mouth is circular, and in the lampreys armed with numerous conical teeth. There is no bony skeleton; the spinal column is represented simply by a thick rod (dorsal cord, notochord) surrounded by a sheath. The skull is cartilaginous, not movable on the vertebral column; is very imperfectly developed, having no jaws, the hyo-mandibular bones and the hyoid arch existing in a very rudimentary state. The few teeth present in the hag-fish are confined to the palate and tongue; those of the lamprey are numerous, conical and developed on the cartilages supporting the lips.

The nervous system is much as in the fishes, the brain with its olfactory, cerebral lobes, thalami, optic lobes, and medulla being developed, the cerebellum in Myxine blended with, in the lamprey free from the medulla. The digestive canal is straight, with no genuine stomach, but the liver is much as in higher Vertebrates. The respiratory organs are very peculiar, being purse-like cavities (whence the name *Marsipobranchii*), in the lamprey being seven in number on each side of the pharynx, opening externally by small apertures; internally they connect with a long cavity lying under the œsophagus, and opening anteriorly into the mouth. The heart is like that of fishes, as are the kidneys. The eyes are minute, sunken in the head and under the skin in the hag (*Myxine*), but larger in the lamprey.

Another extraordinary feature in the class is the single nasal aperture, as opposed to the two occurring in all higher Vertebrates. The aperture leads to a sac, which in the *Myxine* communicates with the mouth (pharynx), but in the lamprey forms a cul-de-sac.

The ovaries and male glands (the sexes being distinct) are unpaired plates suspended from the back-bone, and have no ducts, the eggs breaking through the walls of the ovary, falling into the abdominal cavity and passing out of the abdominal pore. The eggs of *Myxine* are very large in proportion to the fish, enclosed in a horny shell, with a filament at each end by which it may adhere to objects.

The hag-fish is about a foot long and an inch thick, with the head small, a median palatine tooth, and two comb-like rows of teeth on the tongue. There is a single gill-opening a long ways behind the head; there are large mucous or slime-glands on the side of the body, for these fishes are very slimy. The hag lives at considerable depths in the sea; we have dredged one at 114 fathoms in soft deep mud off Cape Ann. It is often parasitic, attaching itself to the bodies of fish, and has been found to have made its way into the body-cavity of sturgeons and haddock.

The lamprey lives both in fresh and salt water. The eggs of the common lamprey, *Petromyzon marinus* (Linn.), are laid in early spring, the fish following the shad up the rivers, and spawning in fresh water, seeking the sea in autumn; small individuals, from five to seven inches long, have been seen by Dr. Abbott attached to the bellies of shad, sucking the eggs out of the oviducts.

The lamprey when six inches long is quite unlike the adult, being blind, the eyes being concealed by the skin; it is toothless, and has other peculiarities. It is so strangely unlike the adult that it was described as a different genus (*Ammocœtes*). *P. nigricans* Lesueur is smaller, and occurs in the lakes of New York and eastward, while *P. niger* Rafinesque is still smaller, and lives in the Western States.

CLASS II. MARSIPOBRANCHI.

Worm-like Vertebrates, without paired fins; notochord persistent; a single nasal sac, six or ten pairs of purse-like gill-sacs, no jaw-bones.

Order 1. *Hyperotetra.*—Nasal duct leading into the mouth. (Myxine.)

Order 2. *Hyperoartia.*—Nasal duct a blind sac, not connecting with the mouth. (Petromyzon.)

Laboratory Work.—The anatomy of these animals is exceedingly interesting; the respiratory sacs and nasal duct can be exposed by a longitudinal section of the head; the relations of the notochord can be best seen by transverse sections; the heart and vessels should be injected. Preparations of the brain should be made, and with care the skull prepared.

CLASS III. PISCES (*Sharks, Rays, Sturgeons, Garpikes, and bony fishes*).

General Characters of Fishes.—We now come to Vertebrates which have genuine jaw-bones and paired fins, and which, in short, are affiliated to the Batrachians, and through them with the reptiles, birds, and mammals. All the fishes agree in having a true skull, to which is attached a movable lower jaw. The brain is well developed, with its lobes for the most part, at least, equivalent to or homologous with those of the reptiles, birds, and mammals, though the cerebral hemispheres are small, and in most fishes of nearly the same size as the optic lobes; the cerebellum is also generally of moderate size. The head forms part of the trunk, there being no neck (except in the *Hippocampidæ*), and the body is usually compressed and adapted in shape for rapid motion in the water.

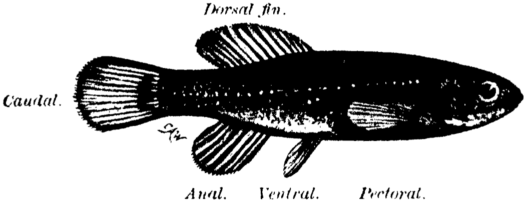

Fig. 388.—The Mud-Minnow.

Paired fins are always primitively developed, though the posterior or ventral fins, at least, are in many cases wanting through the atrophy of parts developed in embryonic life. The pectoral and ventral fins (Fig. 388), which represent the fore and hind legs of higher Vertebrates, are attached to the body or trunk by a shoulder and pelvic girdle. The shoulder girdle is either lyre-shaped or forked, like a bird's wish-bone, curved forward, and with each side connected below; the fishes in this respect differing from the Batrachians (Gill). The shoulder girdle is usually closely connected by a series of intervening bones with the skull, and makes its first appearance opposite the interval between the second and third vertebræ.

The skull and skeleton may be either cartilaginous or bony, and the bones of the head and skeleton very numerous. In some sharks there are 365 vertebræ; in some bony fishes 200, while in the *Plectognathi* (fishes like the sun-fishes and Balistes) there may be no more than fifteen; thus in some fishes there may be about one thousand separate bones. No fishes have a well-defined sternum or breast-bone, this bone appearing for the first time in the Batrachians. The vertebræ are almost always biconcave; this is the simplest, most primitive form of vertebræ; it forms a weak articulation, admitting, as Marsh states, of free, but limited motion.

All fishes breathe by gills, which are supported generally on four or five cartilaginous or bony supports or arches. The gills are never purse-shaped, as in the lampreys, and are mostly situated within the head, in front of the scapular arch.

The mouth is generally armed with teeth varying greatly in number and form, and in the bony fishes especially, not only the jaws, but any bony projections, such as the palatine, pterygoid and vomerine bones, as well as the tongue and pharyngeal bones may be armed with teeth, so that the food is retained in the mouth and more or less torn and crushed before being swallowed.

Fish have no salivary glands. The tongue moves only as a part of the hyoid apparatus upon which it is attached. After being crushed and torn in the mouth the food passes through a short throat or œsophagus into the stomach. The intestine is generally provided at the anterior end with several or numerous cœcal appendages which are especially abundant in the cod. The gut is twisted once or twice before reaching the vent, but is usually much shorter than in the air-breathing Vertebrates, while the vent is placed much nearer the mouth than in the tailed Amphibians, thus separating the trunk into a thoracic and caudal portion. To make up for the short intestine, its absorbing surface is greatly increased in all except the bony fishes by a peculiar fold called the "spiral valve." The rectum always opens in front of the urinary and genital outlets ; except when the latter communicates directly with the rectum, thus forming a cloaca. All fishes have a well-developed liver, usually a gall-bladder, with several gall-ducts ; and in general a yellowish pancreas.

The heart consists of a ventricle and auricle, the latter branchial with a venous sinus (*sinus venosus*) ; while to the ventricle is added an arterial bulb, which subdivides into five pairs of arteries, one for each gill-arch. The *Dipnoi* approach the Amphibians in the possession of a second auricle as well as of genuine lungs, *i.e.*, cellular air-sacs. The lungs are fundamentally comparable with the air-bladder or swimming bladder. It is generally situated below the back-bone, and is developed originally as an offshoot of the œsophagus. It is either free, not connected with the digestive tract, or its original attachment may be retained in the form of the "pneumatic duct," which, when persistent, opens into the œsophagus. In the sharks it is either absent or exists in a rudimentary state.

The kidneys are two voluminous, dark-red lobulated organs, lying close together next to the back-bone, behind, *i. e.*, above the air-bladder, and occupying nearly the whole length of the abdominal cavity. The efferent ducts (ureters) either pass along in front of or by the side of the kidney, and sometimes unite to form a single sac, the outlet of which is situated either behind or below the generative orifice. It has been found that the minute structure of the kidneys of embryo sharks resembles somewhat the segmental organs of worms, the original kidney being composed of bundles of ciliated funnels, like those of worms, combined, however, with Malpighian bodies and renal lobules which do not exist in worms, while all these parts have a common duct, the ureter, which also does not exist in worms, being characteristic of Vertebrates.

In the fishes the sexes are, with a very few exceptions, distinct. The ovaries are large bodies, either discharging the eggs directly, as in the eel, salmon, and trout, into the body-cavity, thence passing along a fold of the peritoneum out of a minute opening situated directly behind the vent, or, as in most bony fishes, there is a duct leading from each ovary to the common outlet. In the sharks and skates (Elasmobranchs) the ovary is single, and the oviducts unite behind to serve as a uterus in such sharks as are viviparous ; or the same parts secrete a shell in the egg-laying sharks (*Scyllium*) and skates.

The reproductive glands of most fishes are, except in the breeding season, so much alike, that it is difficult to distinguish them except by a microscopic examination. In the breeding season the ovaries of the cod, perch, and smelt are very large and yellowish, while the testes are small and white. Fishes, like some Amphibians and many invertebrates, may be able to perform the reproductive functions before they are fully mature ; in fact, some fishes continue to grow as long as they live.

The fishes are not a homogeneous or "closed," *i. e.*, well-circumscribed, type, as the birds and mammals, for the form of the body is liable to great variation, the differences between the subdivisions or orders, families and genera being much greater than in birds and mammals.

The class is divided into three subclasses, viz. : the *Elasmobranchii* (sharks and rays), the *Ganoidea* (sturgeons, garpikes, etc.), and the *Teleostei*, or bony fishes. The classification we adopt is that of Professor Gill.

Subclass 1. Elasmobranchii (*Selachians, or Sharks and Rays*).—These are the most generalized as well as among the oldest of all fishes. In some respects they stand above the bony fishes, with some features anticipating the Amphibians, while in their cartilaginous skeleton, their numerous gill-openings, and their general appearance they are scarcely higher than the embryos of the bony fishes. It would seem as if a shark were an embryo fish, which had been hurried by nature into existence with some parts more perfect than others, in order to serve in the Upper Silurian and Devonian times as destructive agents to the types of invertebrate life which then became extinct, partly through their means. These and ganoid fishes having thus accomplished their work were replaced in the later ages by more highly elaborated and specialized forms, *i.e.*, the bony fishes. Sharks and skates are engines of destruction, having been since their early appearance in the Upper Silurian age the terror of the seas. Their entire structure is such as to enable them to seize, crush, tear, and rapidly digest large invertebrates, and the larger marine members of their own class. Hence their own forms are gigantic, soft, not protected by scales or armor, as they have in the adult form few enemies. Hence they do not need a high degree of intelligence, nor special means of defence or protection, though from their activity the circulatory system is highly developed.

In the general form the sharks are long and somewhat cylindrical, with the head rather large, often pointed, sometimes, in in the hammer-headed shark, extraordinarily broad, with a capacious mouth, situated in the under-side of the head. The body tapers behind, and the caudal portion is unequally lobed, the upper lobe being much longer than the lower, upturned and supported by a continuation of the vertebral column, while the tail-fins of bony fishes are equally lobed and consequently called *homocercal;* those of sharks are unequally lobed, and are therefore said to be *heterocercal.* In this respect they resemble an early stage in the development of bony fishes, such as the trout or herring. Sharks, like bony fishes, have two pectoral and generally two ventral fins; these two pairs of fins corresponding to or homologous with the limbs of air-breathing Vertebrates, and besides this there is one or usually two dorsal fins, and an anal fin, the latter situated behind the vent.

The skin is either smooth or covered with minute placoid scales (see Fig. 385); the integument of such species as are provided with these fine scales forming *shagreen.* While the spinal column is in the sharks usually cartilaginous, and easily cut with a knife, there are different grades of development from certain forms, as the Chimæra, to a well-marked column or series of biconcave vertebræ, with the cartilage in part replaced by bone, forming radiating leaves or plates; while in the rays or skates the anterior part of the column is bony.

The ribs are small, sometimes rudimentary. The skull is rudimentary, without membrane-bones, embryonic in character, forming a simple cartilaginous brain-box, without premaxillary or maxillary bones, the constitution of the jaws being quite unlike that of the bony fishes, the jaws being formed of elements, *i. e.*, "cartilaginous representatives of the primary palatoquadrate arch and of Meckel's cartilage." (Huxley.)

There are no opercular bones such as cover the gill-openings in bony fishes, their place being taken by cartilaginous filaments.

The mouth is armed in most sharks with numerous sharp, flattened, conical teeth, arranged in transverse rows and pointing backwards; they are never fixed in sockets, but imbedded in the mucous membrane of the upper and under jaws. In the Heterodontidæ, represented by *Cestracion* or Port Jackson shark, the teeth are much blunter than in other living sharks, the middle and hinder teeth having broad, flattened crowns, forming a pavement of rounded teeth. The Devonian sharks were in most cases like the *Cestracion* in this respect. In the Carboniferous age, sharks with teeth more like those of modern forms came into existence; and they must have been of a more active nature, the sharp teeth directed backward indicating the rapacity of these monsters, which darting after and seizing their prey were enabled to retain it by the backward-pointed teeth; while the more sluggish Devonian Cestracions kept near the bottom and devoured the shelled mollusks, etc., possibly Orthoceratites, Nautili, and Trilobites, which became nearly extinct about the time the type of pavement-toothed sharks culminated.

The teeth of the skates or rays have obtuse points. In *Myliobatis* the teeth are flattened and united to form a solid pavement, so that the mouths of these large rays are furnished with an upper and nether millstone for crushing and comminuting the thick, solid shells of mollusks. The mouth in both sharks and rays is always situated on the underside of the head, all being ground-feeders. Such sharks as rise to the surface for food seize it by turning over before closing their jaws on the luckless victim.

The throat or œsophagus is wide; the stomach a capacious sac, and the intestine short, separated from the stomach by a pyloric valve. The spiral valve of the intestine is a fold projecting into the cavity of the gut, the fixed edge forming a spiral line around the inner wall of the intestine.

The heart consists of a ventricle and auricle, with an aortic bulb which pulsates as regularly as the heart; and the blood must be sent forward with great force, as the very muscular bulb is provided within with three rows of semi-lunar valves.

The gills are pouch-like, generally five, rarely six or seven, in number, the external openings or gill-slits being usually of moderate size, but sometimes long and large, as in the basking shark. While the clefts open on the side of the neck in sharks, in the skates they are placed beneath the neck.

A *spiracle* or opening leads, in some sharks, from the upper side of the head into the mouth. According to Wyman this is the remnant of the first visceral cleft of the embryo.

In the brain the optic thalami are separate from the optic lobes, the olfactory lobes being large and long in the skates and some sharks. The medulla forms the larger part of the brain. The optic nerves unite, as in higher Vertebrates, forming a common stem or *chiasma*, before diverging to the eyes.

The eyes of some sharks have a third lid or nictitating membrane analogous to that of birds. The ear, except in *Chimæra*, has the labyrinth completely surrounded by cartilage. There are two testes, and usually two ovaries, but in the dog-fishes and the nictitating sharks there is but a single ovary. The oviducts are true "Fallopian tubes," expanding posteriorly into uterine chambers, which unite and open into the cloaca. (Huxley.)

The sharks and skates are not prolific; having but few enemies they do not lose much ground in the struggle for life. The oviparous forms such as certain sharks, skates, and *Chimæra,* lay large eggs enclosed in tough, leathery, purse-shaped cases. The other Elasmobranchiates are viviparous, bringing forth their young alive. In *Mustelus* and *Carcharias* a rudimentary "placenta" analogous to that of Mammals is developed from the yolk. The following account of the development of the dog-fish (*Mustelus*), which is condensed from Balfour, may be found to be applicable to sharks in general:

The blastoderm or germinal disk is a large round spot darker than the rest of the yolk, bordered by a dark line (really a shallow groove). Segmentation occurs much as described in the bony fishes, reptiles, and birds. The upper germ-layer (epiblast) arises much as in the bony fishes, the Batrachians and birds, while the two inner germ-layers are not clearly indicated until a considerably later stage. The segmentation-cavity is formed nearly as in the bony fishes. There is no invagination of the outer germ-layer to form the primitive digestive cavity, as in Amphioxus, the lamprey, sturgeons, and Batrachians, but the Selachians agree with the bony fishes, the reptiles, and birds, in having the alimentary canal formed by an infolding of the innermost germ-layer, the digestive track remaining in communication with the yolk for the greater part of embryonic life by an umbilical canal. This mode of origin of the digestive cavity, Balfour regards as secondary and adaptive, no "gastrula" (Hæckel) being formed as in Amphioxus, etc. The embryo now rises up as a distinct body from the blastoderm, just as in other Vertebrates, and there is a medullary groove along the middle line, and by the time this has appeared the middle and inner germ-layers are clearly indicated. After this development continues in much the same manner as in the chick.

At this time the embryo dog-fish externally resembles the trout; the chief difference is an internal one, the outer germ-layer not being divided into a nervous and epidermal sublayer as in the bony fishes.

The next external change is the division of the tail-end into two caudal lobes. The notochord arises as a rod-like thickening of the third germ-layer, from which it afterwards entirely separates, so that the germ, if cut transversely, would appear somewhat as in the embryo bird.

The primitive vertebræ next arise, and about this time the throat becomes a closed tube. The head is now formed by a singular flattening-out of the germ, like a spatula, while the medullary groove is at first entirely absent. The brain then forms, with its three divisions, into a fore, middle, and hind brain. Soon about twenty primitive vertebræ arise, and by this time the embryo is very similar, in external form, to any other vertebrate embryo, and finally hatches in the form of the adult.

The skate was found by Wyman to be at first long and narrow, the dorsal and anal fins extending to the end of the tail, as in the eel. Soon after it becomes shark-shaped, and finally assumes the skate form. Thus skates pass through a shark-stage, and this accords with the position in nature of skates, since they are, as a whole, a more specialized as well as more modern group than the sharks. Wyman found that there are in the skate at first seven branchial fissures, the most anterior of which is converted into the spiracle, which is the homologue of the Eustachian tube and the outer ear-canal; the seventh is wholly closed up, no trace remaining, while the five others remain permanently open.

The Elasmobranchs are subdivided into two orders (regarded by Gill as super-orders, the *Plagiostomi*, represented by the sharks and rays, and the *Holocephali*, the type of which is *Chimæra*.

Order 1. *Plagiostomi.*—In the sharks and skates the teeth are very numerous; the gill-slits are uncovered. The rays or skates differ from the sharks in their broad, flat bodies, with the gill-slits opening below; the great breadth of the body is due to the enlargement of the pectoral fins which are connected by cartilages to the skull; there is likewise no median articular facet upon the occiput or base of the skull, for the first vertebra.

The most common of our Selachians is the mackerel shark or *Isurus punctatus* (Fig. 389). The head is conical, with the nostrils under the base, and the lobes of the tail are nearly equal. It is from four to eight feet in length, and is often taken in fish-nets, being a surface-swimmer. In the thresher shark (*Alopecias vulpes* Cuvier), the upper lobe of the tail is nearly as long as the body of the shark itself. It grows twelve or fifteen feet in length, and lives on the high seas of the Atlantic.

Nearly twice the size of the thresher is the great basking shark, *Selache* (*Cetorhinus*) *maxima* Cuvier, of the North Atlantic, which becomes nine to thirteen metres (thirty or forty feet) in length. It has very large gill-slits, and is by no means as ferocious as most sharks, since it lives on small fishes, and in part, probably, on small floating animals, straining them into its throat through a series of rays or fringes of an elastic, hard substance, but brittle when bent too much, and arranged like a comb along the gill-openings, the teeth being very small.

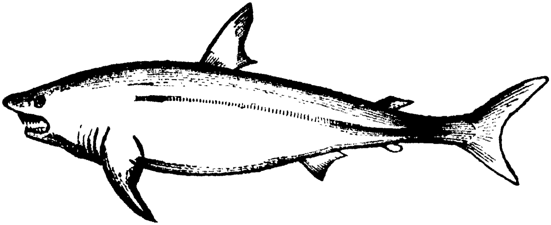

Fig. 389.—Mackerel Shark.—From Tenney's "Zoology."

Among the smaller sharks is the dog-fish (*Squalus Americanus* Storer), distinguished by the sharp spine in front of each of the two dorsal fins. It is caught in great numbers for the oil which is extracted from its liver. The dog-shark (*Mustelus canis* Dekay), which is a little larger than the dog-fish, becoming over a metre (four feet) long, brings forth its young alive. In the European *Mustelus lævis* Risso a so-called placenta is developed, while it is wanting in the *Mustelus vulgaris* of Müller and Henle.

Among the more aberrant sharks is the hammer-headed *Sphyrna zygæna* (Linn.), which grows to the length of twelve feet, and is one of the most rapacious and formidable of the order.

Of the rays and skates, the saw-fish approximates most to the sharks. Its snout is prolonged into a long, flat bony blade, armed on each side with large teeth. *Pristis antiquorum* Latham (Fig. 390), the common saw-fish, inhabits the Mediterranean Sea and the Gulf of Mexico; it is viviparous (Caton.) *Pristis Perroteti* lives in the Senegal River, while *Carcharias gangeticus* is found sixty leagues from the sea.

The genuine skates or rays have the body broad and flat, rhomboidal (owing to the great extension of the thick pectoral fins). Portions of the ventral fins in the males are so elongated and modified as to form intromittent and clasping organs. They swim close to the bottom, feeding upon shell-fish, crabs, etc., crushing them with their powerful flattened teeth. The spiracle is especially developed in the rays, while, as observed by Garman, in the majority of the sharks which swim in midwater or near the surface, the water enters the mouth and passes freely out of the gill-openings, but in the rays, which remain at the bottom, the purer sea-water enters the spiracle from above to pass out of the gill-slits.

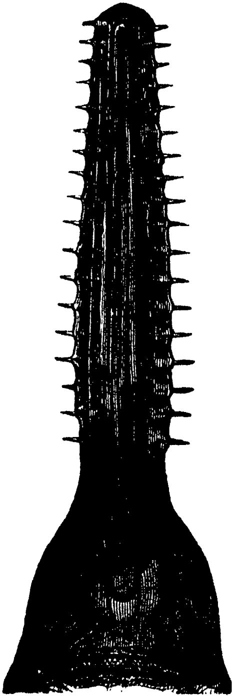

Fig. 390.—Beak of Saw-fish, seen from below, showing its mouth, nostrils, and lateral teeth.—After Owen.

The smallest and most common skate of our northeastern Atlantic coast is *Raja erinacea* Mitchell. It is one half of a metre (twenty inches) in length, and the males are smaller than the females. The largest species is the barn-door skate, *Raja lævis* Mitchell, which is over a metre (forty-two inches) long. *Raja eglanteria* Lacepède (Fig. 391) ranges from Cape Cod to the Caribbean Sea. The smaller figures in Fig. 391 represent respectively the mouth and gill-slits, and the jaws of *Myliobatis fremenvillii* Lesueur.

In the torpedo the body is somewhat oval and rounded. Fig. 392 represents *Torpedo marmoratus*, of the Mediterranean Sea.

Our native species, found mostly in winter, especially on the low sandy shores of Cape Cod, is *Torpedo occidentalis* Storer. Its batteries and nerves are substantially as in the European species. The electrical organs are constructed on the principle of a Voltaic pile, consisting of two series or layers of hexagonal cells, the space between the numerous fine transverse plates in the cells filled with a trembling jelly-like mass, each cell representing, so to speak, a Leyden jar. cells in each battery, each provided with nerves sent off from the fifth and eighth pairs of nerves. The dorsal side of the apparatus is positively electrical, the ventral side negatively so. The electrical current passes from the dorsal to the ventral side. When the electrical ray is disturbed by the touch of any object, the impression is conveyed by the sensory nerves to the brain, exciting there an act of the will which is conveyed along the electric nerves to the batteries,

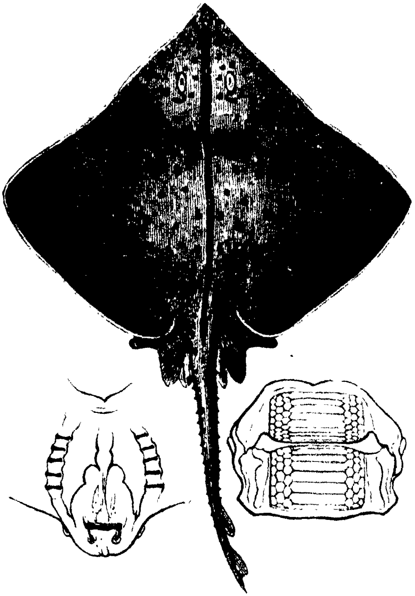

Fig. 391.—*Raja eglanteria*, male. Mouth and gill-slits, jaws and teeth of *Myliobatis fremenvillii* ♀.

producing a shock. The benumbing power is lost by frequent exercise, being regained by rest; it is also increased by energetic circulation and respiration. As in muscular

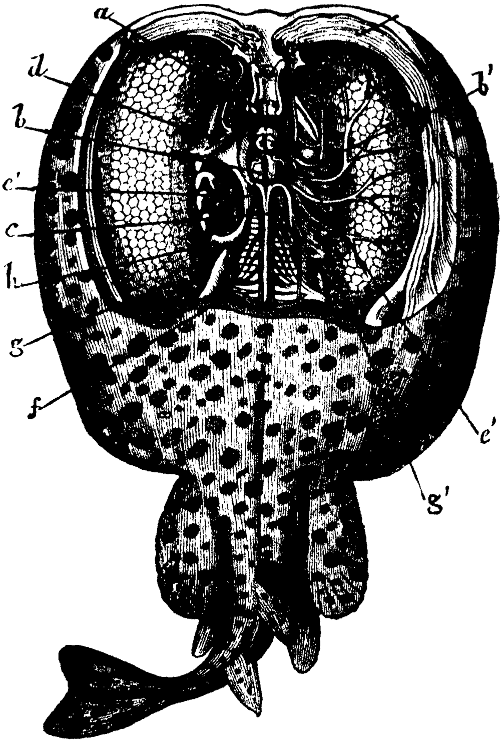

Fig. 392.—*Torpedo marmoratus.* *a*, cerebrum; *b*, the medulla; *c*, spinal cord; *d* and *b'*, electric portion of the trigeminate or fifth pair of nerves; *ee'*, electric portion of the pneumogastric or eighth pair of nerves; *f*, recurrent nerve; *g*, left electric organ entire; *g'*, right electric organ dissected to show the distribution of the nerves; *h*, the last of the branchial chambers; *i*, mucus-secreting tubes.—From Gervais and Van Beneden.

exertion the electrical power is increased by the action of strychnine (Owen).

Marey has more recently made interesting experiments on the torpedo, examining the discharge of this fish with the telephone. Slight excitations provoked a short croaking sound. Each of the small discharges was composed of a dozen fluxes and pulsations, lasting about one fifteenth of a second. The sound got from a prolonged discharge, however, continued three to four seconds, and consisted of a sort of groan, with tonality of about *mi* (165 vibrations), agreeing pretty closely with the result of graphic experiments.

Marey has also studied the resemblance of the electrical apparatus of the electrical ray or torpedo and a muscle. Both are subject to will, provided with nerves of centrifugal action, have a very similar chemical composition, and resemble each other in some points of structure. A muscle in contraction and in tetanus executes a number of successive small movements or shocks, and a like complexity has been proved by M. Marey in the discharge of the torpedo.

The sting-rays (*Trygon*) have no caudal fin, but the spinal column is greatly elongated, very slender, and armed with a long, erect spine or "sting." Some live in fresh water; several species of sting-rays (Potamotrygon) inhabit the large rivers of Brazil and Surinam, as the Amazon, Tapajos, Madeira, and Araguay, digging holes in the sand, in which they lie flat and await their prey. In this connection it may be said that *Raia fluviatilis* of India has been taken near Rampur, nearly 1000 miles above tide-reach.

Myliobatis has the teeth forming a solid plate or pavement. The devil-fish (*Cephalopterus diabolus* Mitchell) of the coast of South Carolina and Florida is the largest of our rays, being eighteen feet across from tip to tip of its pectoral fins, and ten feet in length, weighing several tons. It sometimes seizes the anchors of small vessels by means of the curved processes of its head and swims rapidly out to sea, carrying the craft along with it.

Order 2. *Holocephali.*—This small but interesting group is represented by *Chimæra* of the north Atlantic, and *Callorhynchus* of the antarctic seas. In these fishes the four gill-openings are covered by an opercular membrane; thus approaching the true bony fishes, and there are but four teeth in the upper and two in the lower jaw. The brain of Chimæra is said by Wilder to combine characters of those of

Selachians, Ganoids, and Batrachians. *Chimæra plumbea* Gill lives in deep water off the coast of New England.

Subclass 2. Ganoidei (*Garpikes, Lung-Fishes*).—The term Ganoid was applied to these fishes from the form of the scales, which in most of the species are angular, square, or rhomboidal and covered with enamel, as seen in the common garpike. In others, however, as in the Amia and Dipnoans, the scales are rounded or cycloid. These fish, *i.e.*, both the genuine Ganoids and *Dipnoi*, were the characteristic fishes of the Devonian age, which has consequently been called the Age of Fishes, there being no bony fishes (*Teleostei*) at that time. The forms were much larger than at present, far more numerous in species, genera, and families, and they, with the sharks, were the rulers of the sea.

At the present day the type is nearly extinct, being represented by such isolated forms as the sturgeon, the paddle-fish, the lung-fish (*Dipnoi*), the garpikes, and the American mud-fish (*Amia*). Like most of the palæozoic types of life, the Ganoids were both generalized forms and also combined the characters of classes of animals not then in existence ; in other words they were synthetic or comprehensive types. Thus in forms like Amia, the Teleostean fishes were anticipated ; in the *Dipnoi*, with their external gills and lungs, not only the Amphibians, but even the reptiles were indicated in their hearts with two auricles, just as the Trilobites and *Merostomata*, as indicated by the structure of the living king-crab, combined with the structure of Crustaceans, features which became in a degree reproduced in the terrestrial scorpions and spiders which subsequently appeared. Owing to this intermixture of ancient and modern characteristics, this reaching up and out of the piscine type of life over into the amphibian and reptilian boundaries, the classification, *i. e.*, actual position in nature of the Ganoids, becomes very difficult, and the views of naturalists regarding their systematic position are very discordant. If, as insisted on by Gill, we recognize the fact that the Ganoids are an *older*, more generalized, and therefore more elementary group, and the osseous fishes a newer, more highly specialized group, and that there is a natural series of forms leading from the sturgeon, which is nearest the Elasmobranchs, up through the Dipnoans to the true Ganoids, and that the latter, through *Amia*, leads to the bony fishes, we shall have a clue to the intricate relations existing between them and the other subclasses of fishes.*

The Ganoids of the present day are well nigh confined to fresh water, the sturgeons alone living in the sea as well as ascending rivers; though the Devonian and carboniferous forms occur as marine fossils.

In synthetic forms, like the Ganoids, it is difficult to find absolute characters separating them from the Elasmobranchs on the one hand and the Teleosts on the other. The diagnostic characters are the following: the skeleton is either wholly cartilaginous, or partly or wholly bony; the skin is either smooth, or with cycloid, or usually with ganoid scales; the gills are free; the gill-opening is covered with an opercular bone; the first fin-rays generally sharp; the air-bladder with a pneumatic duct; the embryos sometimes with external gills.

The spinal column is usually cartilaginous; in the Dipnoans, the sturgeons, the paddle-fish and allies, the notochord, with its sheath, is persistent; while in *Polypterus* and *Amia* the spinal column is completely bony, the vertebræ being *amphicœlous*, *i. e.*, biconcave; while in the garpike (*Lepidosteus*) the vertebræ are convex in front and concave behind. The cartilaginous skull is covered by broad, thin membrane-bones, as seen in the sturgeon. The tail is heterocercal, the lobes being, in *Amia*, nearly equal.

The brain is as in the bony fishes, but the optic nerves unite in a chiasma. The heart and aortic bulb are as in the Elasmobranchs, and all but *Lepidosteus* have a well-developed spiral valve in the intestine, the valve being rudimentary

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*** Although strongly inclined to regard the Dipnoans from their amphibian and reptilian characters as types of a subclass, *Dipnoi*, yet in deference to the principles stated by Gill, which we had previously followed independently in the classification of the neocaridan and palæocaridan Crustacea, we here adopt the classification of Prof. Gill.**

in the garpikes. The oviducts communicate with the ureters as in the sharks and amphibians. The different modifications of Ganoid structure may be observed in the examples of the different orders.

Many of the Ganoids of the Upper Silurian and Devonian rocks belonged to the groups *Cephalaspidæ* and *Placodermata.* In the Cephalaspids, represented by the singular *Cephalaspis Lyellii* of Agassiz, the broad head was covered by a single semi-circular plate, with large orbits above, the mouth being below. The pectoral fins were rayless folds of the skin; the body behind the head was covered with rhomboidal scales, and provided with a dorsal fin. The *Pteraspis* had a head-shield composed of seven pieces. Among the Placoderms, *Pterichthys* had a plated head half as long as the body, the tail short and sealed. These fishes, the earliest known Vertebrates, were bottom-feeders. Nothing is known as to the nature of their jaws or teeth.

Order 1. *Chondroganoidei.*—In these Ganoids the dorsal chord is not ossified; the skull is cartilaginous, covered with membrane-bones; they are either toothless or with small teeth. The skin is naked as in the paddle-fish, or protected as in the sturgeons with very large, bony, solid plates. The sturgeons have the snout long and pointed, with the mouth underneath, and toothless. *Acipenser sturio* Linn. is the common sea-sturgeon of our coast, ascending rivers. The shovel-nosed sturgeon, *Scaphirhynchops platyrhynchus* has a spade-like snout. It inhabits the waters of the Mississippi Valley. Salensky has studied the embryology of the Russian sturgeon. The freshly-laid eggs are two millimetres in diameter, the yolk undergoes nearly total segmentation, thus connecting most Vertebrates in which the eggs only partially segment, with the Amphioxus, lampreys, and amphibia, in which segmentation is total. The skeleton is developed much as in the Elasmobranchs. The sheath of the notochord develops in three weeks after hatching. At the end of the third week the upper and lower vertebral arches appear, arising as in other fishes. The skull is indicated in two or three weeks after hatching.

The singular spoon-bill, *Polyodon folium* Lacepède, is five feet long; it is smooth-skinned and has a snout one-third as long as the body, and spatulate, with thin edges. It has a very wide mouth with minute teeth, and lives on small Crustacea. It abounds in the Mississippi, and its larger tributaries.

Order 2. Dipnoi.—The lung fishes are so called from the fact that often being in pools and streams liable to dry up, they breathe air directly, having true lungs, like those of Amphibians, as well as gills. From the nature of their lungs and heart, the Dipnoans are quite different from all other fishes, anticipating in nature the coming of Amphibians, while on the other hand the notochord and sheath is persistent, and as they were characteristic and more numerous in Devonian times, they may be said to be a prematurative type.

The body of the Dipnoans is somewhat eel-shaped, though not very long in proportion to its thickness, and is covered with cycloid scales. The pectoral and ventral fins are long, narrow, and pointed, and there is a long caudal fin which is *protocercal*, a term proposed by Wyman to designate the form of the caudal fin of embryo sharks. In fact, the tail of the young garpike, as of embryo Teleosts or bony fishes, is at first protocercal, afterwards being heterocercal in adult Ganoids, such as the garpike, and in the embryo and early free stage of most bony fishes; the tail in the latter becoming finally homocercal or equal-lobed. Thus the tail of the Dipnoans may be said to be embryonic, *i.e.*, protocercal.

The spinal column is represented by a simple notochord and sheath; within the latter the basal ends of the bony neural arches and ribs, and near the tail the lower (hæmal) arches are imbedded. The skull is cartilaginous. The extremity of the lower jaws supports large tooth-like plates (dentary plates) which shut in between the few palatine teeth; in *Ceratodus* these plates are single, and in all Dipnoans these single dentary plates are very characteristic of the group. The narrow pectoral and ventral fins are supported by a single, median, many-jointed cartilaginous rod, to which is attached fine fin-rays, supporting the thin edge of the fin.

The spiral valve and cloaca are present in the intestinal tract. In Polypterus the cerebral hemispheres are larger than the olfactory lobes, and there is an optic chiasma; the heart has besides the right large auricle, a left smaller one which receives the blood from the lungs, and a single ventricle, as in Amphibians and most reptiles; they have true nostrils. The lungs are like those of Amphibians, and in addition they possess both internal and external gills (Fig. 393), the latter nearly aborted in the adult.

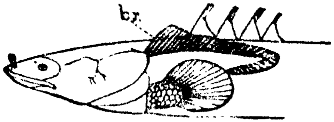

Fig. 393.—External gills of a young *Polypterus bichir*. *br*, external gills.

The genus *Ceratodus* was originally named by Agassiz, from teeth found in Jurassic and Triassic strata in Europe. Living specimens were found by Mr. Krefft in Queensland, Australia, and called *Ceratodus Fosteri* Krefft (Fig. 394). This fish is rather more elementary in form than *Lepidosiren*, the body being stouter, and the large scales of the body, with the fin-like paddles and distinctly rayed vertical fins, cause it to resemble more closely ordinary bony fishes than Lepidosiren (Günther). Moreover the lung is single, and not used so much as the two perfect lungs of *Lepidosiren*. It attains a length of six feet. It can breathe by either gills or lungs alone. When, Günther thinks, the fish is compelled to live during droughts in thick muddy water charged with gases which are the product of decomposing organic matter, it is obliged to use its lungs. The gills are more like those of ordinary bony fishes than those of *Lepidosiren*. It lives on the dead leaves of aquatic grasses, etc. The local English name is "flat-head," the

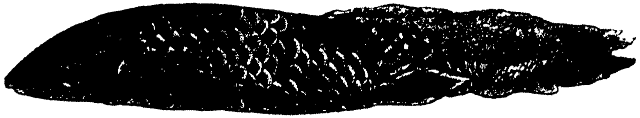

Fig. 394.—*Ceratodus*, or Australian Lung-Fish. (The tail in nature ends in a point.) —After Günther; from Nicholson.

native name being "barramundi." Nothing is known of its breeding habits or mode of development. The eggs when ready to be laid are 2.5 millimetres in diameter. The lower part of the oviduct is much as in Menopoma. Fossil teeth of Ceratodus occur in the Jurassic beds of Wyoming, and two species have been found in still older beds in Illinois, regarded by Cope as either Upper Carboniferous or Permian. Thus, as remarked by Günther, we have in *Ceratodus* a genus which has survived from the Triassic period.

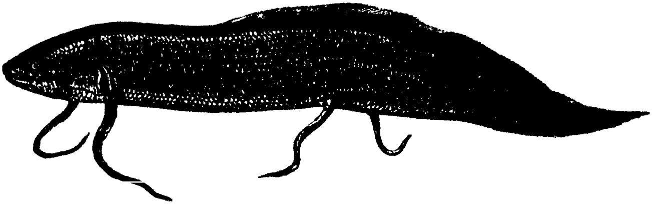

Fig. 395.—*Protopterus annectens*, a Lung-fish of Africa. One third natural size.

The lung-fish are distinguished by two well-formed lungs, and the narrow ribbon-like fins. In *Lepidosiren paradoxa* Fitzinger, there are five gill-arches, with four slits, and the body is rather longer, more eel-like, with a blunter snout than in *Protopterus*. It grows to one metre in length, and inhabits the rivers of Brazil. This is represented in Africa by the closely allied *Protopterus annectens* Owen (Figs. 395 and 396 skeleton), which has six gill-arches, with three pairs of external gills in the young. It is 40–70 centimetres in length. It lives on leaves in the White Nile, Quilimani, Niger, Gambia, and their tributaries. It buries itself in the mud a foot deep. Günther states that numerous examples

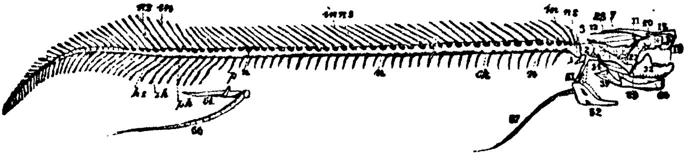

Fig. 396.—Skeleton of *Protopterus annectens*, showing the protocercal tail and the simple rod-like limbs, the pelvic and shoulder girdles, and the nature of the jaws. *ch*, notochord; *p*, bones representing the hæmal arches attached to the notochordal sheath; *hs*, hæmal spines; *in*, *ih*, rays of the caudal fin.—After Owen.

of *Lepidosiren* "have been kept in captivity, but none have shown a tendency to leave the water."

The modern *Dipnoi* represent the Devonian fishes *Holoptychius*, *Dipterus*, and *Phaneropleuron*, and the American *Dinichthys Torrelli* of the Devonian rocks of Ohio, which is said by Newberry to have been about five metres (from fifteen to eighteen feet) in length, and a metre in thickness, being inferior only in size to the *Asterolepis*, a Placoderm of the old red sandstone of Great Britain.

Order 3. *Branchioganoidei.*—Here belongs the *Polypterus* of the Nile and Senegal. In these Ganoids the tail is either protocercal or heterocercal; the scales are cycloid or rhomboid. The dorsal fin is long, subdivided into divisions, each with a separate ray and spine. *Polypterus bichir* Geoffroy (Fig. 397) has a protocercal tail. The young has external gills (Fig. 393). It inhabits the river Nile, *P. senegalus* the Senegal. *Calamoichthys* differs in having no ventral fins and in its elongated form. It inhabits the rivers of Old Calabar. Allied to these living forms are the Devonian *Osteolepis*, *Cœlacanthus*, and *Holoptychius*.

Order 4. *Hyoganoidei.*—This group is represented by the garpike and *Amia* or mud-fish of the United States, which is an annectant form connecting the Ganoids with the Teleosts. In these fishes the spinal column is bony, the tail partially heterocercal.

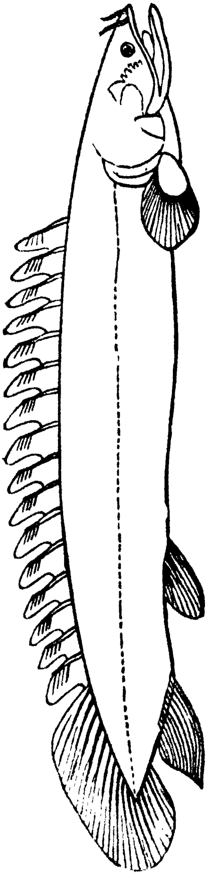

Fig. 397.—*Polypterus bichir.*—From Cuvier.

In *Lepidosteus* (Fig. 398, *L. osseus* Agassiz) the body is long, the jaws long and armed with sharp teeth, the vertebræ are opisthocœlous, and the scales are large and rhomboidal, while the air-bladder is cellular, lung-like. Fossil species occur with those of *Amia* in the tertiary rocks of the West. *Lepidosteus osseus* Agassiz, the bony gar, with a long, slender snout, is sometimes five feet long; *L. platystomus* Rafin. has a short nose, while the alligator gar, *L. spatula* Lacépède, has a short and wide snout, and grows to a larger size (nearly three metres) than the other species, and inhabits the Mississippi Valley. The garpikes are carnivorous, very rapacious, and are said to destroy large numbers of food-fishes. They usually remain near the surface of the water, emitting bubbles of air and apparently taking in a fresh supply. Wilder has observed *Amia* inhaling air, and remarks that "so far as the experiments go, it seems probable that, with both *Amia* and *Lepidosteus*, there occurs an inhalation as well as exhalation of air at pretty regular intervals, the whole process resembling that of the *Menobranchus* and other salamanders, and the tadpoles, which, as the gills shrink and the lungs increase, come more frequently to the surface for air." Both of these fishes are very tenacious of life and withstand removal from water much better than bony fishes and sturgeons, on account of the lung-like nature of their air-bladder. Wilder shows that there is a series of forms, mostly Ganoids, from the *Amia* and *Lepidosteus* in which the pneumatic duct enters the throat on the dorsal side, up to *Lepidosiren* in which it enters the throat on the ventral side, like the air-tube or trachea of Amphibians and higher Vertebrates.

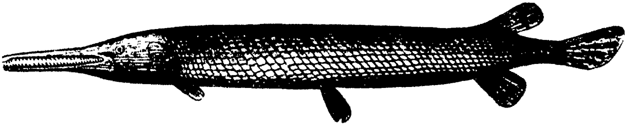

Fig. 398.—Garpike. From Tenney's Zoology.

The breeding habits and external changes in form of the garpikes have been described by Mr. A. Agassiz. The gars, which are nocturnal in their habits, appear on the shores of Lake Ontario at Ogdensburg in immense numbers between the middle of May and the 8th of June, remaining at other times of the year in deep water.

The young begin to hatch about the end of May. At first the embryo gar possesses an unusually large yolk-sac, while the notochord is very large; otherwise posteriorly it resembles the young of bony fishes. It differs, however, in its large mouth, which is surmounted with a hoof-shaped depression edged with a row of projecting suckers, by which it attaches itself, hanging immovable, to stones; the eye and brain is smaller than in bony fishes. The tail is at first protocercal, beginning on the second day to become heterocercal. On the third day the gill-covers form rectangular flaps, and the first traces of the pectoral fins appear, while the snout becomes longer. By the fifth day the traces of the dorsal, caudal, and anal fins appear. When a little over three weeks old it assumes a more fish-like form; the sucking disk has nearly disappeared, the lower jaw greatly lengthened, and the gill-covers extend to the base of the pectoral fins. When between two and three weeks old the young gar-fish is 20 millimetres (¾ inch) long. The young rise to the surface to swallow air, as in the adult. Soon after this it is of the form first discovered and figured by Wilder. The gar-fish, according to Agassiz, bears some resemblance to the sturgeon in certain stages of growth, and in the formation of the pectoral fins from a lateral fold, as well as by the mode of growth of the gill-openings and the gill-arches, while it closely resembles the young of bony fishes in the development of the posterior part of the body, by the mode of origin of unpaired fins from the embryonic fin-fold, and by the mode of formation of the fin-rays, and of the ventral fins.

The mud-fish, *Amia calva* Linn., is like an ordinary bony fish in form, with rounded scales; the caudal fin "masked heterocercal," the snout is short and rounded, and the air-bladder is large and cellular. It attains a length of two thirds of a metre, and occurs in the Mississippi Valley and as far east as New York. A fossil form closely allied to *Amia* dates back to the Cretaceous Age, and the genus *Caturus* is a Liassic and Oolitic genus.

Subclass 3. Teleostei (*Bony fishes*).—We now come to a type of fishes which, within very recent geological times as well as during the present period, has become differentiated or broken up into thousands of species, corresponding to the complexity of their physical environment as compared with the simple features of the physical geography of Devonian and Carboniferous land-masses. Like most of the larger groups of animals, as the Decapod Crustacea, and especially the insects, as well as the mollusks, the bony fishes have attained an astonishing amount of specialization, as if the tree of icthyic life, taking root in the Silurian Age, and sending out but a few branches in later Palæozoic times, had suddenly, in the Cretaceous and Tertiary Ages, thrown out a multitude of fine branches and twigs intertwining and spreading out in a way most baffling to the systematist.

The essential, diagnostic characters of the bony fishes, *i.e.*, such as separate them from the Elasmobranchs and Ganoids, are as follows: The skeleton is bony, the vertebræ being separate; the outer elements of the scapular arch are simple, the inner elements for the most part bony and usually three or two in number; the pectoral fins are without any bone representing the humerus, and are connected with the scapular arch by several (generally four) narrow bones (Gill). The optic nerves cross one another. The gills are free, usually four on each side, and with several opercular bones. The heart is without a cone, but with an arterial bulb, and with but two valves at the origin of the aorta. The intestine is destitute of a spiral valve.

The student should dissect a typical Teleost, such as a fresh-water or sea perch, with the aid of the following account of its anatomy. The drawing and account here given of the anatomy of the sea-perch have been prepared by Dr. C. Sedgwick Minot. The common sea-perch or cunner (*Tautogolabrus adspersus* Gill, Fig. 399) resembles the fresh-water perch very closely in its anatomy, the most noteworthy difference being the absence of the cœca at the pyloric end of the stomach in the marine species; with this exception the following description applies almost equally well to the fresh-water perch, so that this account will be available for western students who have not access to specimens of the cunner.

The perch has the general form of a flattened spindle, for it tapers down at either end and is compressed laterally. There is no neck marked off externally, and the head appears as the direct continuation of the body, but separated from it by a fissure on either side; this is the opening of the gills, which extends from above downwards and curves forward, nearly meeting its fellow on the median line of the under jaw; upon opening the gill-slit the pectinate or comb-like gills or branchiæ are seen within. There are four sets of branchial filaments, each set attached to a separate descending arch, in front of each of which is a slit leading into the cavity of the mouth; but there is no slit behind the last gill. The branchiæ are protected externally by the gill-cover or operculum, which is attached in front, but is free behind, where it forms the front edge of the gill-slit; it is composed of four distinct parts: 1. The præoperculum nearest the eye, and with its lowest corner almost a right angle; its posterior and vertical edge is furnished with numerous minute projecting spines. 2. Appended to the underside of the margin thus armed is the operculum. 3. Below the præoperculum is the interoperculum, which partially covers up 4, the suboperculum. Each of these parts has a separate bony support; all four bones are developed only in the Teleosts; in sturgeons, for example, there is only an operculum, to which in other Ganoids other parts are added; in Selachians the whole apparatus remains undeveloped.

The mouth is placed in front; the upper lip is capable of independent motion, being supported by the præmaxillary bones, which are but loosely attached to the cranium, though in many other fishes the union is closer. The eyes are large and lidless; just in front of each eye is an opening of the size of a pin's head; these openings lead into the nasal sacs, of which there are two, but both are without communication with the mouth; in higher vertebrates, from the *Dipnoi* upwards and in *Myxine,* there is such a communication. In the *Marsipobranchii* there is but a single median nasal sac.

The ear has no external opening, being completely encased in bone. Nearly parallel with the line of the back extends a continuous row of yellow spots marking the lateral line (Fig. 399, *L*), along which are found the pore-like openings of the so-called muciparous glands.

All fish have fins of two kinds—unpaired and paired; the latter, four in number, correspond to the limbs of other Vertebrates. The unpaired fins are first developed on a continuous median flap of integument, which extends along the back, around the tail, and on the underside as far forward as the anus; cartilaginous or bony rays are developed in it as a support. In the adult fish the fold is generally discontinuous, being usually separated into three distinct fins—dorsal, caudal, and anal; the dorsal fin is frequently, the anal fin sometimes subdivided. The fin-rays are (1) either simple pointed rods, or (2) jointed and branching. All the rays of the caudal fin, and the posterior rays of the dorsal and anal fins, are branching. In some Malacopterygians all the rays are branching; in many, however, the first ray is simple in the dorsal and anal fins, while fishes like the perch and cunner are distinguished by having several or many of the anterior rays of the dorsal and anal fins simple and pointed. In the cunner half the rays of the dorsal and the first two of the anal fin are simple.

The pectoral fins are attached to the side of the body and are large and rounded. The ventral fins lie further back near the median ventral line; they are smaller than the pectorals. The position of the ventrals varies in different fish, and is much used in classification. The anus lies immediately in front of the anal fin.

The body is covered by scales, which overlap one another from before backward; their free edges are rounded and smooth, hence they are called cycloid. These scales, as in all Teleosts, are ossifications of the underlying cutis, and are covered by the epidermis; they were formerly wrongly supposed to be epidermal structures.

To dissect a perch the side-wall of the mouth must be removed, then the gill-cover; study the arrangement of the gills. Next make an incision along the median ventral line from the level of the pectoral fins to just before the anus, and following the upper edge of the body-cavity upward and forward cut away the body-wall, taking care not to injure the large swimming-bladder above, nor the heart in front. Now open the pericardial cavity, which lies ventrally immediately behind the gills (see Fig. 399, *Ht*). Cut away the muscular masses around the back of the head; expose the cavity of the brain, and remove the loose cellular tissue around the nervous centres. If the gills of one side are excised and the intestine drawn out, the dissection will appear very much as in Fig. 399.

The cavity of the mouth widens rapidly and continues as the branchial chamber or pharynx (*G*), whence we can pass a probe outward through any of the gill-slits. There is a single row of sharp-pointed teeth in front on both the under and upper jaws; in the pharynx above and below there are rounded teeth. At the side of the pharynx are the four gill-slits and the four arches; the inner surface of the anterior three arches is smooth, while the arch behind the fourth slit is much modified in shape and is armed with tubercles and teeth. The entrance of each slit is guarded in front and behind by a row of projecting tubercles appended to the arches. On the outside of each arch, except the fourth, is a double row of filaments, richly supplied with blood-vessels which, shining through, give a brilliant red color to the gills; on the fourth arch there is but a single row. At the upper and posterior corner of the pharynx is the small opening of the short œsophagus. The branchial chamber has an upward extension on the sides of which lie the pseudobranchiæ (*Ps*), accessory respiratory organs not connected with the gills proper, and receiving their blood-supply from distinct arteries. There are no salivary glands.

The œsophagus dilates almost immediately to form the stomach (partly concealed in the figure by the liver, *Li*), which seems hardly more than a dilatation of the intestine (*In*). This last is of nearly uniform size throughout, and after making three or four coils terminates at the anus, immediately in front of the urinary and genital apertures. When *in situ*, the terminal portion of the intestine or the *rectum* extends straight along the median ventral line. The liver (*Li*) forms an elongated light-brown mass resting upon the stomach. The elongated gall-bladder lies between the liver and stomach, somewhat imbedded in the substance of the former. There is no pancreas, though it is present in some fishes. The spleen (*Sp*) lies between the stomach and intestine, in the mesentery; it is dark reddish-brown in color.

The air-bladder (*S*) is a single large sac, placed in the dorsal part of the body-cavity. Its glistening walls are composed mainly of tough fibrous tissue. The pneumatic duct, by which the bladder communicates with the œsophagus in many fishes, is wanting in the perch as in nearly all other Teleosts. The air-bladder normally contains only gases. It conceals most of the kidneys, which extend the whole length of the body-cavity on either side of the middle line, as two long strips of a deep though dull red. They project beyond the air-bladder in front (*Ki*) and behind (*Ki'*). Their anterior ends are somewhat separated from one another by the intervening pharynx. The ureters open into a urinary bladder (*bl*) behind the anus.

The ovary is single and varies greatly in size according to the season. In the male the sexual glands are double. Each testis (*T*) is an elongated, whitish, lobulated organ, placed immediately below the swimming-bladder, and continues posteriorly with the spermiduct, which opens immediately behind the anus.

The heart (*Ht*) lies in the triangular pericardial cavity; it consists of two portions, the dark-colored venous chamber, or auricle, above, and the lighter-colored arterial chamber, or ventricle, below. The auricle receives from above two large veins, one from either side; these veins are called the *ducti Cuvieri*. Each Cuvierian duct, as can be seen in the figure, ascends beside the œsophagus, and there receives a large jugular vein from in front, and a large cardinal vein from behind. Furthermore, a large vein, the sole representative of the *vena cava* of higher Vertebrates, passes from the liver, near its anterior end, through the pericardium, and empties into the Cuvierian ducts near their common auricular orifice.

The walls of the auricle are comparatively thin ; the auriculo-ventricular orifice is provided with valves, which prevent the blood flowing back into the auricle. The walls of the ventricle are thick and very muscular ; from the upper end of the ventricle close to the base of the auricle springs the *bulbus arteriosus*, a muscular cylinder, which, running horizontally forward, passes out through the pericardium, and is continued as the less muscular aorta (*A*) underneath the branchial arches along the median line ; the aorta gives off branches on both sides, one to each arch to supply the branchiæ ; the vessels after ramifying are gathered together, to again form a single trunk, which passes backward immediately underneath the spinal column ; it is called the descending aorta.

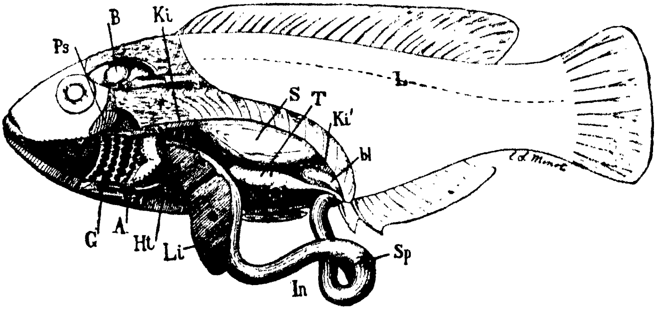

Fig. 399.—Anatomy of the Cunner, male. *L*, lateral line ; *Ht*, heart ; *G*, pharynx ; *Ps*, pseudobranchia ; *Sp*, spleen ; *S*, air-bladder ; *Ki*, *Ki'*, kidneys ; *bl*, bladder ; *T*, testis ; *A*, aorta ; *B*, brain ; *In*, intestine ; *Li*, liver ; *G*, gills.—Drawn by C. S. Minot.

The body and pericardial cavities are called *serous*, because their lining membranes are always moist with serum, a watery fluid, very much like blood-plasma. The lining of the body-cavity is named the *peritoneum*, and forms a continuous covering around the viscera. It is important to observe that the various organs simply project into the body-cavity and do not lie really inside of it. In fishes we find the disposition of the parts to correspond more closely with the fundamental type of Vertebrate structure than it does in higher forms, in which further modifications have supervened. The pharynx still has its distinctive character ; the pericardium lies at the base of the neck, instead of in the thorax as in the higher Vertebrates. The heart still preserves its primitive division ; on the other hand, the swimming-bladder is a special adaptation of the piscian type, while the frequent absence of the pancreas is a peculiarity of fishes the meaning of which is not yet understood.

The brain (*B*) does not occupy the whole of the cranial cavity, but is imbedded in a large accumulation of cellular tissue. In order to study the brain satisfactorily, it should be exposed from above, laying bare at the same time the optic nerves and muscles. The two olfactory lobes are followed by two lobes (*H*), the cerebral hemispheres, and immediately behind them two larger lobes (*Q*), the *corpora bi-* or *quadrigemina* (optic *lobes*, not optic thalami) ; further back follows a single median lobe (*Cb*), the *cerebellum*, somewhat conical in shape and resting upon the *medulla oblongata* (*M*), from which spring various nerves, and which, tapering backward, is continued as the spinal cord. In front appear the very large and conspicuous optic nerves (*Op*), the right nerve passing obliquely to the left eye, the left nerve to the right eye running under the right nerve, but forming no chiasma ; each optic nerve is a plaited membrane, folded somewhat like a fan when shut up, an arrangement occurring only among fishes. In a side-view of the brain (Fig. 400, *B*), the mode of origin of the optic nerves and their origin from the optic lobes can be clearly seen ; it further shows the various forms of the lobes of the brain, and the large *inferior lobes* (*L*) below the corpora quadrigemina ; these lobes are very remarkable and difficult to homologize.

The eyes lie in two sockets, separated by an interorbital septum (Fig. 400, *S*). The eyeball has the form of an oblate spheroid, and is moved, as in all Vertebrates, by four *recti* and two *obliqui* muscles. The recti spring from around the exit of the optic nerve from the brain-case, and thence diverge to be inserted into different parts of the eyeball ; above is the *rectus superior* (*Rs*) ; towards the interorbital septum (*S*) *rectus internus* (*Ri*), opposed to the last is the *rectus externus* (*Re*), and below is the *rectus inferior*, not shown in the figure. In Teleosts both oblique muscles, the *superior* (*Os*) and *inferior* (*Oi*), arise from the front of the orbit near the interorbital septum. The disposition of the

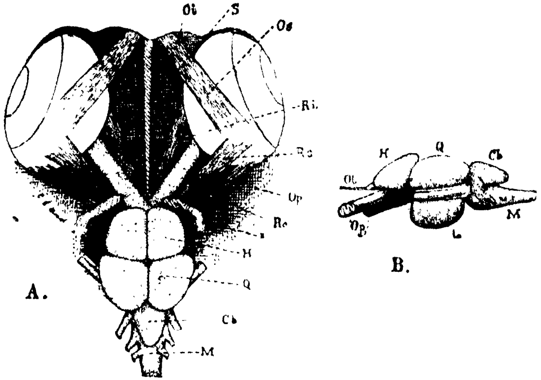

Fig. 400.—Anatomy of the brain of the Cunner, dorsal and side view. *B*, *Ol*, olfactory lobes; the crura and the thalami not represented.—Drawn by C. S. Minot.

recti is very constant, but the obliqui vary considerably in their origin in different Vertebrates.

If a perch be cut through transversely, so that the section passes through the fore-part of the air-bladder, and the anterior portion then looked at from behind, a very instructive view will be obtained, as in Fig. 401. The best sections can be made by first freezing the fish. The vertebral column (*V*) appears a little above the middle; overlying it is the neural canal with the spinal cord; immediately below it is the descending or dorsal aorta (*Ao*), on either side of which follow the kidneys (*K*), resting directly upon the air-bladder (*Bl*). Lowermost is the body-cavity, with the stomach (*S*), and intestine (*In*), surrounded by the liver, which has been almost entirely removed. The rest of the section is occupied by muscles, which, it will thus be seen, make up the main bulk of the body. (Minot.)

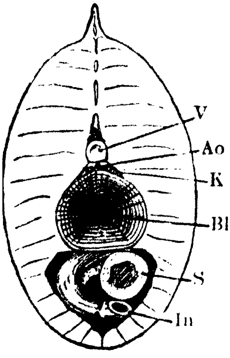

Fig. 401.—Transverse section through the middle of the body of a Cunner.—Drawn by C. S. Minot.

The so-called "mucous canal" or lateral line of fishes and Amphibians is sensory. It consists of small masses of nerve-epithelium, arranged in linear series along the sides of the head and body, having hair-cells continuous with nerves. They are called "nerve-buttons" or "nerve-heaps." According to Schultze, their office appears to be to appreciate mass-movements of the water, and more particularly vibrations, which have longer periods than those appreciated by the ear (Dercum). In the blind-fish of the Mammoth Cave a row of sense-papillæ is situated on the front of the head, supplied with nerve-fibres sent from the fifth pair of nerves (Wyman).

The angler (*Lophius piscatorius*) has long been known to possess hinged teeth, capable of being bent inward toward the mouth, but by virtue of the elasticity of the hinge at once resuming the upright position when pressure is removed from them. *Anableps* and *Pœcilia* have also movable teeth. The hake, a voracious predatory fish, and in a less degree other *Gadidæ*, are possessed of hinged teeth.

The nature of respiration is intimately connected with the production of sounds by fishes. Recent researches by Jobert on certain unusual modes of breathing in fishes are of special interest. He has examined certain fishes of the Amazons, *i.e.*, species of *Callichthys*, *Doras*, *Erithrinus*, *Hypostomus* and *Sudis gigas* or "piraruců" of the natives, the latter being allied to the herring. In the *Callichthys* the intestine is transformed into a respiratory organ. When the water dries up it emigrates to other pools or streams, creeping by means of its pectoral fins. This fish can live twenty-four hours out of the water with impunity.

In the gigantic piraruců, the swimming-bladder is a long sac, and the upper part does not look like that organ, being spongy, areolar, reddish-brown, friable, and intimately pressed to the dorsal and lateral walls of the body; its color recalls that of the lungs of a bird, and functionally it resembles the latter.

Among accessory breathing organs are the lamellate cavity of the *Anabas*, and the sac-like appendages which are in connection with the gill-cavity, and extend under the muscles of the body of *Amphipnous cuchia*, *Gymnarchus* and *Saccobranchus singio.*

The noises produced by certain fishes are due primarily to the action of the pneumatic duct and swimming-bladder, while different kinds of noises are made accidentally or involuntarily by the lips or the pharyngeal or intermaxillary bones, as in the tench, carp and a large number of other fishes. Over fifty species of fish are known by Dufosse to produce sounds of some sort, and Abbot has increased the number in this country. The swimming-bladders of *Trigla* and *Zeus* have a diaphragm and muscles for opening and closing it, by which a murmuring sound is made. The loudest sounds are made by *Pogonias chromis*, the drum-fish. In some *Cyprininæ*, Siluroids and eels the sound is made by forcing the air from the swimming-bladder into the œsophagus. In the sea-horse (*Hippocampus*), the sounds are made by the vibrations of certain small voluntary muscles.

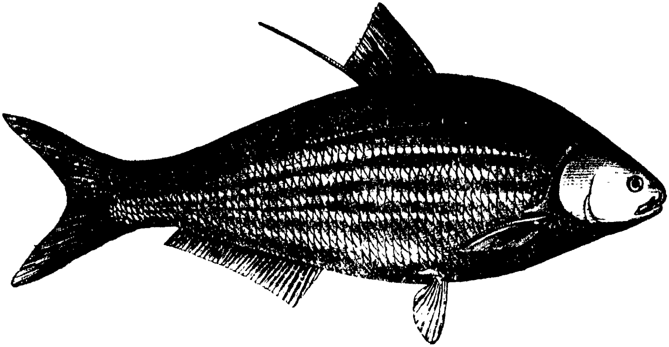

Fig. 402 —Gizzard Shad.

Dr. C. C. Abbot has in this country discovered that the mud sun-fish (*Acantharchus pomotis*) utters a deep grunting sound; the gizzard shad (*Dorosoma cepedianum*, Fig. 402) makes "an audible whirring sound;" the chub-sucker or mullet (*Erimyzon oblongum*) "utters a single prolonged note accompanied by a discharge of air-bubbles;" the cat-fish (*Amiurus lynx*) produces "a gentle humming sound;" eels utter a more distinctly musical sound than any other of those observed by Abbot, who states that "it is a single note, frequently repeated, and has a slightly metallic resonance." It should also be noticed that the organs of hearing in many musical fishes are said to be unusually well developed, hence these sounds are probably love-notes; and Abbot notices the fact that these fishes are dull-colored during the reproductive season, as well as at other times, while voiceless fishes, such as the perch, common sun-fish, chub, roach, etc., are highly colored during the breeding season, and thus the sexes are mutually attracted in the one case by music, and in the other by bright colors. Finally the sounds of fishes may be said to be homologous with those of reptiles, birds and mammals, the air-bladder being homologous with the lungs of the higher Vertebrates, while the pneumatic duct is comparable with the trachea of birds and mammals.

In swimming, the propelling motion is mainly exerted by the tail, the movements of which are somewhat like those of an oar in sculling. The spines of the tail-fin are movable, and are capable of being brought into such a position that the fin will meet with less resistance from the water while the tail is bent, then straightened, and it is when being straightened that the fish is propelled. The movements of the pectorals and ventrals are to steady the fish and to elevate and depress it, while the dorsal and anal fins steady the body and keep it upright, like a dorsal and ventral keel.

Among viviparous bony fishes are certain Cyprinodonts (as *Anableps* and *Pœcilia*), the eel-like *Zoarces*, and the blind-fish of the Mammoth Cave. A small family of Californian marine fishes, in form resembling the sun-fish (Pomotis) are called by Agassiz *Embiotocidæ*, from the fact that they bring forth their young alive. *Embiotoca Jacksoni* Agassiz, which is twenty-seven and a half centimetres (10½ inches) long, has been known to produce nineteen young, each about seven and a half centimetres (3 inches) long.

During their reproductive season, many bony fishes, such as the stickleback, salmon, and pike, are more highly colored than at other times, the males being especially brilliant in their hues, while other secondary sexual characters are developed. The female deposits her eggs either in masses at the surface of the water, as the goose-fish, or at the bottom on gravel or sand as do most other fishes, the male passing over them and depositing his "milt" or spermatic particles. The egg has a thin transparent shell, and the yolk is small, covered with a thick layer of the "white."

The eggs after fertilization undergo partial segmentation, the primitive streak, notochord, nervous cord, and brain develop as in the chick, but that the embryo is to become a fish is soon determined by the absence of an amnion and allantois, and by the fact that the germ lies free over the yolk like a band.

In the pike the heart begins to beat about the seventh day, and by this time the alimentary canal is marked out. The primitive kidneys are developed above the liver. The air-bladder arises as an offshoot opposite the liver from the alimentary canal, and the gall-bladder is also originally a diverticulum of the intestine. The urinary bladder in the fish is supposed to be the homologue of the allantois of the higher Vertebrates. The principal external change is the appearance of the usually large pectoral fins.

The embryo pike hatches in about twelve days after development begins, and swims about with the large yolk-bag attached, and it is some seven or eight days before the young fish takes food, living meanwhile on the yolk mass. The perch hatches in twelve days after the egg is fertilized, and swims about for eight or ten days before the yolk is absorbed. The gills gradually develop with the absorption of the yolk.

The tail in most bony fishes is at first protocercal, then becoming heterocercal as in the adult sharks, but subsequently, after the fish has swam about for a while and increased in size, it becomes homocercal or symmetrical. The scales are the last to be developed.

In the large size of the pectoral fins, the position of the mouth, which is situated far back under the head, the heterocercal tail, the cartilaginous skeleton and uncovered gill-slits, the embryo salmon, pike, perch, etc., manifest transitory characters which are permanent in sharks.

The bony fishes date back to the Jurassic period, but did not become numerous until the Cretaceous and especially the Tertiary Period. The Green River beds of Wyoming abound in their remains.

The Teleosts are divided into eight orders, in an ascending series as follows: *Opisthomi, Apodes, Nematognathi, Scyphophori, Teleocephali, Pediculati, Lophobranchii* and *Plectognathi.*

Order 1. *Opisthomi.*—The fishes of this group are characterized by the separation of the shoulder-girdle from the head. The ventral fins are either abdominal or wanting. The typical genus is *Notocanthus*, in which the body is elongated, with a proboscis-like snout.

Order 2. *Apodes.*—In this group, also, the scapular arch is free from the skull, while the maxillary bones are rudimentary. The branchial apertures are unusually small, and there are no ventral fins, while the body is very long, cylindrical, snake-like. The order is represented among many other forms by the common eel (*Anguilla*), the conger-eel, and the *Muræna* of the Mediterranean Sea. The conger-eel (*Conger oceanicus* Gill) ranges from Newfoundland to the West Indies. Gill, as well as Günther and others, regards a long transparent ribbon-like fish, described under the name of *Leptocephalus* as the young of the conger-eel.

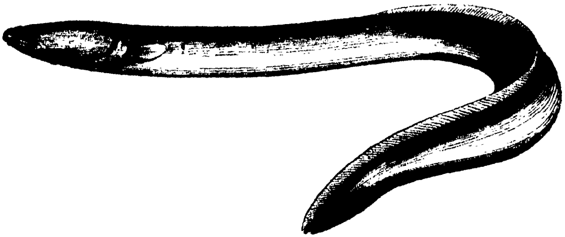

Fig. 403.—Common Eel, *Anguilla acutirostris.*

The common eel, *Anguilla acutirostris* (Fig. 403), occurs on both sides of the Atlantic, on the North American coast as far south as Cape Hatteras, and in inland rivers and lakes. The sexes do not differ externally, and internally only as regards the form of the reproductive glands. The ovaries form two ribbon-like masses extending from the liver to just beyond the vent and attached by one edge to the walls of the body, with the free edge hanging downwards. When in spawn the ovary is very thick, white, and the eggs can be seen with the naked eye, being nearly one half millimetre in diameter. When ripe they break through the wall of the gland and drop into the body-cavity, there being no oviduct, and pass out of the genital opening situated directly behind the vent. The male glands occupy the same position as the ovaries of the female, but are smaller, narrower, and distinctly lobulated. Out of about six hundred specimens of eels, only four males have yet been found in this country. These had testes like those described by Syrski in the Italian eel (*A. vulgaris*), while Packard detected the mother cells, and Mr. Kingsley observed moving active spermatozoa. It is probable that the eel descends rivers in October and November, spawning in the autumn and early winter at the mouth of rivers, and in harbors and estuaries in shallow water. By the end of the spring the young eels are two or three inches long, and then ascend rivers and streams. They grow about an inch a month, and the females do not spawn at least before the second year, *i. e.*, when about twenty inches long. Mr. Mather estimates that the ovary of an eel weighing six pounds when in spawn contains upwards of 9,000,000 eggs.

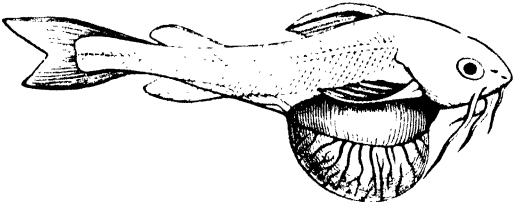

Fig. 404.—A Siluroid Fish, *Arius*. Young with the yolk not absorbed.

Order 3. *Nematognathi.*—This group is represented in North American waters by the catfish and horned pout. The name of the order (from νῆμα, νήματος, thread, and ς, jaw) is in allusion to the filaments or barbels growing out from the jaws, and which are characteristic of the members of the group. The upper jaw is formed by the intermaxillary bones only, while the supra-maxillary bones form the bases of the large barbels. The suboperculum is always absent, as is also the symplectic; the supra-occipital and parietal bones are co-ossified. The skin is either naked or with bony plates. The air-bladder connects by a duct with the roof of the œsophagus. While a few forms are marine, most of the Siluroid fishes are inhabitants of the rivers of tropical countries, a large number being characteristic of the rivers of Brazil. All the North American species belong to the family *Siluridæ*, of which the common representatives are the horned pout and western catfish. In these forms the skin is naked. The horned pout, *Amiurus atrarius* Gill, ranges from New England to Maryland and the Great Lakes. It breeds in New England in holes in gravel during the midsummer. The Great Lake catfish, *Amiurus nigricans* Lesueur, is abundant in the Great Lakes, and is about a metre (2–4 feet) in length. The blind catfish, *Gronias nigrilabris* Cope, inhabits a subterranean stream tributary to Conestoga River in Eastern Pennsylvania.

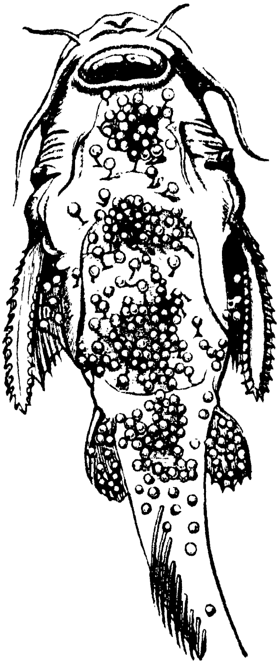

Fig. 405.—*Aspredo*, a Siluroid fish, seen from beneath, with its egg-capsules attached by slight stalks.

Among the exotic South American Siluroids are *Arius* (Fig. 404) and *Aspredo* (Fig. 405) of Guiana. In *Arius* and some of its allies in South America the eggs are carried by the males in their mouth, from five to twenty being thus borne about until the young hatch. They are probably caught up after exclusion and fertilization. Some of these eggs are half an inch in diameter. Dr. Day states that the same habits occur in certain Indian species of *Arius* and *Osteogeniosus*. A species of *Arius* was found by Steindachner, at Panama, to carry its eggs in a fold of the skin of its belly; afterwards the males bear them about in their mouth.

The females of *Aspredo* have on the ventral surface horny, stalked capsules, which contain eggs from one to two millimetres in diameter; the capsules disappear as soon as the young hatch.

Malapterurus electricus Lacépède, of the Nile, is electrical, the electric cells forming a layer directly beneath the skin and enveloping the whole body, except the head and fins. The cells are minute, lozenge-shaped, about one and a half millimetres in diameter. They are supplied by a nerve from the spinal cord. The shock is comparatively feeble, but suffices for defence, "the fish being protected by its electrifying coat, as is the hedgehog by its spines." (Owen.)

Order 4. *Scyphophori.*—This order, first named and characterized by Cope, derives its appellation from the Greek *σκύφος*, a bowl, and *φέρω*, to bear, in allusion to a peculiarity of the pterygoid bone, which is enlarged, funnel-shaped, and excavated by a bowl-like chamber which expands laterally and is covered by a lid-like bone. The brain has a peculiar plicated organ over the cerebellum; the air-bladder is simple, communicating by a duct with the intestinal canal. The order comprises two families, the members of which inhabit the rivers of Africa; they are the *Mormyridæ*, represented by a number of genera and species, and the *Gymnarchidæ*, of which *Gymnarchus niloticus* is the only known species.

Order 5. *Teleocephali.*—These are our common types of fishes, and are, whether we consider their individual structure or the number of specific forms, the most highly developed, *i. e.*, specialized, of the class. The name is derived from *τέλειος*, perfect, and *κεφαλή*, head, in allusion to the high degree of elaboration and diversity in the bones of the head. The skeleton is usually completely ossified. The bones of the skull and of the jaws are fully developed. The lower jaw is attached to the skull by a suspensorium of several well-marked bones, including a symplectic, while the hyoid and gill arches are well developed, as is the scapular arch. The brain has small olfactory lobes and a small cerebellum. The scales are generally present, and either ctenoid (*i.e.*, rough-edged) or cycloid (*i.e.*, rounded but smooth on the edge). The common examples are the carp, herring, trout and salmon, pike, perch, cod, and flounder.

Turning now to some of the more characteristic members of the order, we first notice one of the lowest Teleosts, the electrical eel (*Gymnotus electricus* Linn.) of South America, which is two metres in length, and is characterized by its greatly developed electrical batteries. These are four in number, situated two on each side of the body, and together form nearly the whole lower half of the trunk. The plates of the cells are vertical instead of horizontal, as in the torpedo, while the entire batteries or cells are horizontal, instead of vertical, as in the electrical ray. The nerves sent to the batteries of the eel are supplied by the ventral branches of about two hundred pairs of spinal nerves.

Succeeding these and allied forms are the herrings (*Clupeidæ*), represented by the common English herring, *Clupea harengus* Linn., which inhabits both sides of the North Atlantic, extending on the American side from the polar regions to Cape Cod; the alewife, *Pomolobus pseudoharengus* Gill, which ranges from Newfoundland to Florida; the shad, *Alosa sapidissima* Storer, which has the same geographical distribution as the alewife; and the menhaden or pogy, *Brevoortia tyrannus* Goode, which extends from the coast of Maine to Cape Hatteras. These, with the cod, hake, haddock, salmon, and a few other species, comprise our most valuable marine food-fishes. The fisheries of the United States yield about $9,000,000 annually, whilst those of Great Britain amount to about $8,000,000, and those of Norway about $14,000,000.

The herring is a deep-water fish which visits the coast in spring in immense schools, in which the females are three times as numerous as the males, to spawn, selecting shoal water from three to four fathoms deep in bays, where the eggs hatch. At this season, and early in the summer, hundreds of millions are caught, especially on the Canadian, Newfoundland, and Labrador coasts. The English whitebait is the young of the herring. The herring is caught in deep nets with meshes large enough to capture individuals of ordinary size, the nets having a finer mesh than those used for the mackerel fishery.

The alewife and shad are said to be *anadromous*, from their habit early in spring of visiting the coast and ascending rivers in vast numbers to spawn. The eggs are of moderate size; the ovaries are said to contain about 25,000, and at times as many as 100,000 or 150,000 eggs. They are discharged near the surface, sinking slowly to the bottom. The time between impregnation and hatching varies from about three to six days, according to the temperature. The shad eats little or nothing in fresh water, being then engaged in the act of reproduction. In the sea they live on small Crustaceans, such as *Mysis*, etc. The menhaden is now put up as a substitute for sardines, and is of great value as fish-bait, especially in the mackerel fishery, and for its oil.

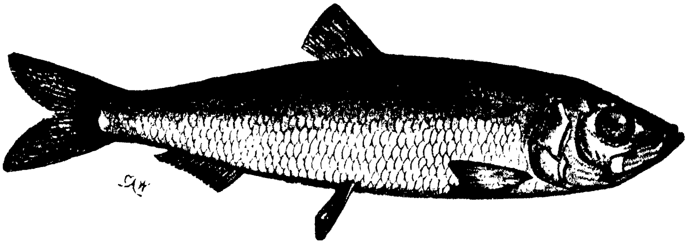
Fig. 411.—The Herring, *Clupea harengus*, one third natural size. From the *American Naturalist*.

The family *Salmonidæ* comprise the salmon, trout, and whitefish, with a number of species and varieties. The species of the genus *Salmo* have not more than eleven rays to the anal fin, while the salmon of the west coast, *quinnat*, has fifteen or sixteen anal rays. The *Salmo salar* Linn. sometimes weighs eighty pounds. It is common to Europe as well as Northeastern America. In the autumn the salmon ascends rivers to spawn, penetrating as near the source as possible. During the breeding season the males differ decidedly from the females, in the long, slender, hooked snout, the body being thin and high-colored. The eggs are very large, exceeding a pea in size, and are laid in shallow holes made in the gravel of streams. The extreme young are banded and called *parr*; when about a year old, and of a bright silvery color, before descending the rivers to the sea, it is called a *smolt*; after its return from the sea into fresh water it goes by the name of *grilse*; and finally, after returning a second time from the sea, it assumes its name of salmon. The trout, *Salmo* (*Salvelinus*) *fontinalis* Gill and Jordan, also breeds in the autumn and early winter; it is not anadromous, living permanently in streams and ponds.

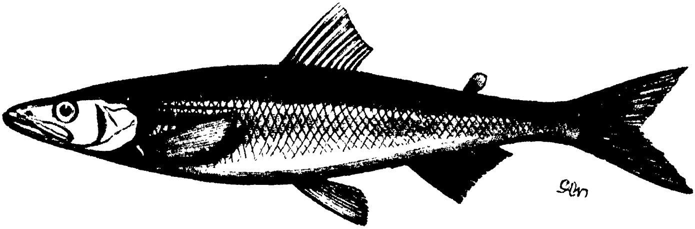

Fig. 412.—The Smelt—*Osmerus mordax*—one half natural size.—From the *American Naturalist*.

An allied family embraces the smelts, *Osmerus eperlanus* Linn., and *O. mordax* Mitchill, which live on both sides of the Atlantic, and range from Nova Scotia to Virginia. The capelin, *Mallotus villosus* Cuvier, is valuable as bait in the cod fishery. It spawns in the summer. The males are distinguished by a prominent lateral ridge along the sides of the body and are more numerous than the females.

Belonging to the same suborder or group of families as the *Salmonidæ* is the family *Galaxiidæ*, represented by *Galaxias* and *Neochanna* (Fig. 413), in the latter of which the ventral fins are absent.

The carps (*Cyprinus*), shiners and minnows abound everywhere in the Northern States in ponds and weedy streams. The breeding habits of the dace (*Rhinichthys atronasus* Mitchill) have been observed by Dr. Gregg. The females spawn over "nests" or shallow depressions two feet in diameter in running brooks about a foot deep; the male passes over the eggs fertilizing them; then the pair bring small pebbles which are dropped over the eggs, until layer after layer alternately of eggs and pebbles are deposited, when a heap is formed, the young hatching out and remaining among the pebbles until old enough to venture out into the stream. The dace is closely allied to the chub (*Semotilus rhotheus* Cope, Fig. 415). Succeeding them are the suckers (family *Catostomidæ*) of which *Catostomus teres* Lesueur is an example.

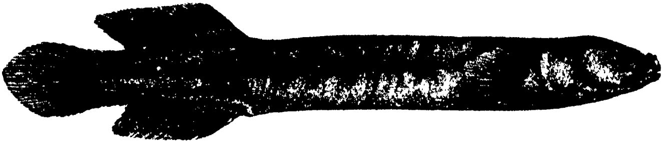

Fig. 413.—*Neochanna.*—From Lütken.

The blind fish of the Mammoth and other caves, and of adjoining wells connecting with subterranean streams, are remarkable for the rudimentary state of the eyes, and consequently of color. There are several species, the most common and largest being *Amblyopsis spelæus* De Kay; this species is viviparous. Representing the family *Umbridæ* is the mud-minnow (*Melanura limi* Kirt., Fig. 414).

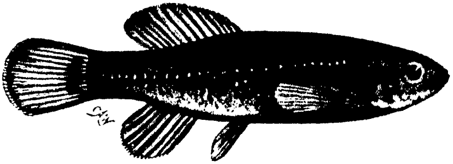

Fig. 414.—Mud-Minnow.—From Abbot.

The flying-fish represent another family. Their pectoral fins are very broad and large. They dart from the water with great speed without reference to the course of the wind and waves. They make no regular flying motions with their pectoral and ventral fins, but spread them out quietly, though very rapid vibrations can be seen in the outstretched pectoral fins. They usually fly farther against the wind than with it, or if their track and the direction of the wind form an angle. Most flying-fish which fly against or with the wind continue in their whole course of flight in the same direction in which they come out of the water. Winds which blow from one side on to the original track of the fish bend their course inward. All fish which are at a distance from the vessel hover in their whole course in the air near the surface of the water. If in strong winds they fly against the course of the waves, then they fly a little higher; sometimes they cut with the tail into the crest of the waves. Only such flying-fish rise to a considerable height (at the highest, by chance, five metres above the surface of the sea) whose course in the air becomes obstructed by a vessel. In the daytime flying-fish seldom fall on the deck of the ship, but mostly in the night; never in a calm, but only when the wind blows. (Moebius.)

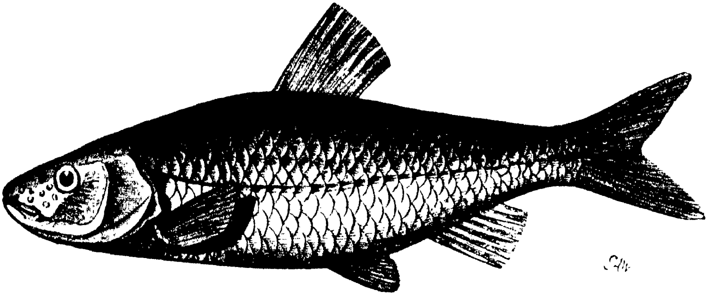

Fig. 415.—The Large Chub, *Semotilus rhotheus*, one fifth natural size.—From Abbot.

Following the flying-fish is the family represented by the silver gar or bill-fish (*Belone longirostrus* Mitchill, Fig. 416).

The sucker (*Echeneis remora* Linn.) occurs along the whole coast of the United States, and is found all over the tropical and subtropical seas. It is provided with a broad oval sucker on the upper side of the head, by which it adheres to other fish or even to ships, and may thus be transported long distances. Another noticeable member of the order is the blue-fish (*Pomatomus saltatrix* Linn., Fig. 417), so valuable as a food-fish.

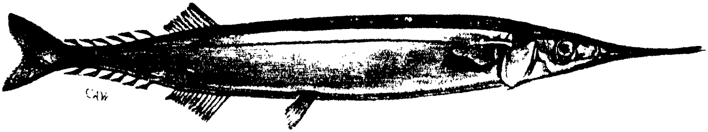

Fig. 416.—The Bill-fish, *Belone longirostrus*.—From the *American Naturalist*.

The dolphin (*Coryphæna*) is sometimes found upon our coast, but it is essentially a pelagic fish, occurring only out of sight of land upon the high seas. The pilot-fish is also a pelagic form.

The percoid fishes are represented by the perch (*Perca fluviatilis* Linn.), which spawns in winter, making slight hollows in the gravel in shoal places in ponds; their movements can be watched through the ice. On the other hand, the sun-fish or bream (*Eupomotis aureus* G. and J.) spawns in the summer time, making a nest, which they scoop out of the river bottom. The banded sun-fish (*Mesogonistius chætodon* Gill) occasionally scoops out a little basin in the sand, in which it deposits its eggs late in the spring. The spotted

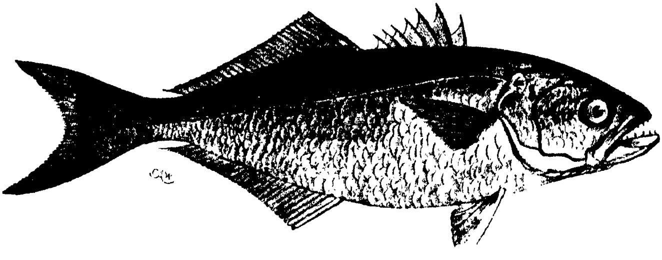

Fig. 417.—The Blue-fish, *Pomatomus saltatrix*, one sixth natural size.—From the *American Naturalist*.

sun-fish (*Enneacanthus obesus* Gill, Fig. 418) lives in muddy streams, burying itself in the mud in winter. Of similar mud-loving habits is the mud-minnow (*Melanura limi* Agassiz), which spawns in the spring. The pirate perch (*Aphredoderus sayanus* De Kay) occupies the nest of common sun-fish, and with the female guards it and afterwards the young till they are nearly a centimetre (two-fifths inch) in length, when they are left by their parents. (Abbot.)

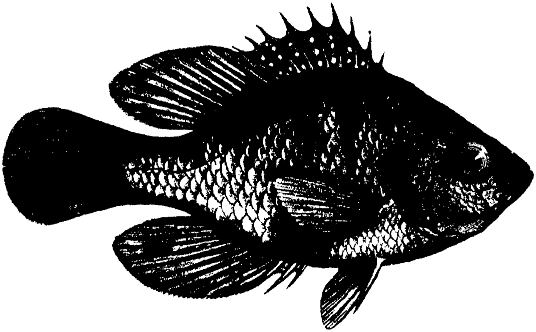

Fig. 418.—The Spotted Sun-fish, *Enneacanthus obesus*.—After Abbot.

The darters, *Etheostomidæ*, belong near the perches, and comprise the smallest of fishes. They inhabit the streams of the Mississippi Valley. A common example is the sand-darter (*Pleurolepis pellucidus* Agassiz, Fig. 419).

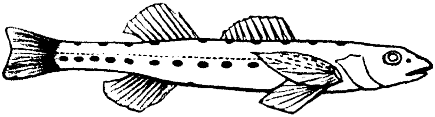

Fig. 419.—Sand-Darter.—After Jordan.

The male stickleback (*Gasterosteus*) makes an elaborate nest of leaves, etc., suspended in mid-water, within which it remains watching the eggs and young.

One of the most valuable food-fishes is the mackerel (*Scomber scombrus* Linn., Fig. 420), whose range is from

Greenland to Cape Hatteras. It remains in deep water during the late autumn and winter, approaching the coast in May and June for the purpose of spawning, its annual appearance being very regular. The number of eggs deposited in one season by each female is said to be from five to six hundred thousand. *After spawning they move northward, following the coast until they are checked by the coolness of the water, when they return, and in November seek the deep water again. When spawning they do not* take the hook ; they are then lean ; but at the time of their departure from the coast they are fat and plump. (Blake.) The eggs of the mackerel as well as of the cod are so light as to rise to the surface, where they develop. Allied to the mackerel, though of great size, are the horse-mackerel and the sword-fish, whose upper jaw is greatly prolonged.

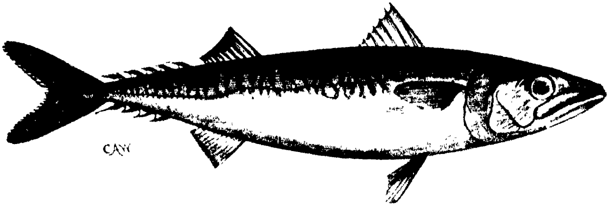

Fig. 420.—The **Mackerel**, *Scomber scombrus*, one quarter natural size.—After Blake.

The singular *Anabas* of the East Indies is the representative of a small group of fishes called *Labyrinthici* or labyrinth-fishes, in allusion to a cavity on the upper side of the branchial cavity on the first gill-arches, containing a labyrinthine organ, which consists of thin plates, developed from the upper pharyngeal bones, enabling the fish to live for a long time out of water. *Anabas scandens* Cuvier, of the fresh waters of India, will travel over dry land from one pond to another, and is even said to climb trees by means of the spines in its fins.

Near the head of the order stands the cunner (*Tautogolabrus adspersus* Gill), whose anatomy is represented by Figs. 404–406 Passing over the tautog, the voracious wolf-fish (*Anarrhichas*), the blennies (*Blenniidæ*), in which the body is long and narrow, and the viviparous eel-pout (*Zoarces*), the cottoids or sculpins, and a number of allied forms, we come to the hake (*Merlucius bilinearis* Gill), the haddock (*Melanogrammus æglefinus* Gill, Fig. 421), and cod (*Gadus morrhua* Linn., Fig. 422), all of which extend northwards from Cape Hatteras, the cod abounding on both sides of the Atlantic, being a circumpolar fish. The cod does not, as formerly supposed, migrate along the coast, but seeks the cool temperature to which it is adapted by gradually passing in the early summer from shallow to deep water, and returning as the season grows colder. It visits the shallow water of Massachusetts Bay to spawn about the first of November, and towards the last of the month deposits its eggs. About

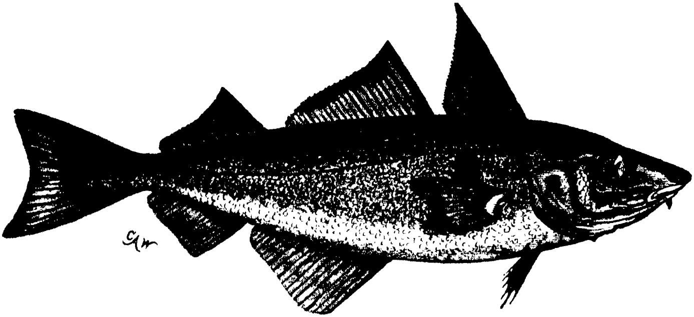

Fig. 421.—The Haddock, *Melanogrammus æglefinus*.—From the *American Naturalist*

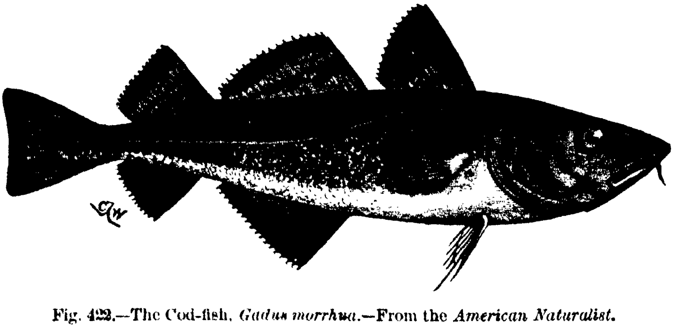

Fig. 422.—The Cod-fish, *Gadus morrhua*.—From the *American Naturalist*.

eight or nine million of eggs are annually deposited by each female. (Blake.) The eggs laid by the cod rise to the surface of the water, on which they float. The young fish hatch on the New England coast in twenty days after they are extruded. Several millions of cod were artificially hatched at Gloucester, Mass., in the winter of 1878–9, by the United States Fish Commission; it has thus been demonstrated that this fish can be artificially propagated.

The cod is the most important of all the food-fishes, whether we consider the number taken and the amount of capital involved in the cod-fishery. It abounds most on the Grand Banks of Newfoundland. The breeding habits of the haddock, hake and pollock are probably like those of the cod.

Fierasfer is a small eel-like fish, *with a long, thin tail. It* is typical of a peculiar family, and is noteworthy from being a "commensal" or boarder in the digestive canal of Holothurians, etc. *F. acus* Brünn. lives in Holuthurians, and another species in a star-fish (*Culcita*). The *Brotulidæ* are fishes allied to the cod, but constituting a distinct family. Most of them are salt-water species, but allied forms (*Lucifuga subterraneus* and *Stygicola dentata*) live in subterranean waters in Cuba.

At the head of *Teleocephali* stand the flounders, halibut and soles, which are an extremely modified type of the order. In these fishes the body is very unsymmetrical, the fish virtually swimming on one side, the eyes being on the upper side of the head. The upper side is colored dark, due as in other fishes to pigment-cells; the lower side is colorless, the pigment-cells being undeveloped. When first hatched the body of the flounder is symmetrical, and in form is somewhat cylindrical, like the young of other fishes, swimming vertically as they do, and with pigment-cells on the underside of the body. Steenstrup first showed by a series of museum specimens that the flounder was not born with the eyes on the same side of the head, but that one eye gradually passed from the blind to the colored side. Mr. A. Agassiz has studied the process, and finds that the transfer of the eye from the blind side to the colored side occurs very early in life, while all the facial bones of the skull are still cartilaginous, long before they become hard and ossified, *i.e.*, when the flounder (*Plagusia*) is twenty-five millimetres (one inch) long. "The transfer of the eye from the right side to the left takes place by means of a movement of translation, accompanied and supplemented by a movement of rotation over the frontal bone." Young flounders, when less than two inches in length, are remarkably active compared with the adults, darting rapidly through the water after their food, which consists principally of larval, surface-swimming crustaceans, etc. (A. Agassiz.) The common flounder from Nova Scotia to Cape Hatteras is *Pseudopleuronectes Americanus* of Gill.

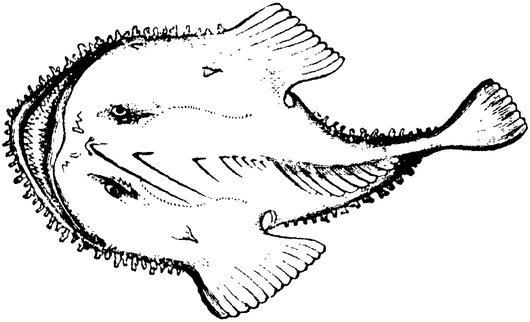

Fig. 423. Goose-fish, one tenth natural size.—From Tenney's *Zoology*.

Order 6. *Pediculati.*—The type of this order is the goose-fish. The name was given to the group from the long slender bones supporting the pectoral fins. The gill-openings are small and placed in axils of the pectoral fins. *Lophius piscatorius* Linn., the goose-fish or angler (Fig. 423), has an enormous mouth, and swallows fishes nearly as large as itself. The head and fore-part of the body is very large; the skin is naked, scaleless. Its eggs are laid in broad, ribbon-like, thin gelatinous masses, two metres long and half a metre wide, which float on the surface of the ocean.

Order 7. *Lophobranchii.*—The tufted-gilled fish—such the name of the order indicates—have a fibro-cartilaginous skeleton; a single opercular bone, while the snout and lower jaw are prolonged into a tube, with the mouth at the end. The chief peculiarity, however, is the gills, which are developed in the form of a row of tufted lobes on each side of the branchial arches. The scales are large, forming angular plates arranged in longitudinal rows (Gill). In *Solenostoma* of the Indian Ocean the female carries the eggs in a pouch formed by the union of the ventral fins with the integument of the breast.

The male of the pipe-fish (*Syngnathus peckianus* Storer) receives from the female the eggs, and carries them in a small pouch under his tail, which is open beneath through its whole length. This singular mode of masculine gestation is still farther perfected in the sea-horse (*Hippocampus hudsonius* De Kay, Fig. 424), which lives off-shore from Cape Cod to Cape Hatteras). The pouch is situated on the breast. The male, by simple mechanical pressure of its tail, or by rubbing against some fixed object, as a shell, forces the fry, to the number of about a thousand, out of its brood-pouch, the young at this time measuring about twelve millimetres (5–6 lines) in length. In the young the head is at first rounded, the snout being short and blunt (Lockwood).

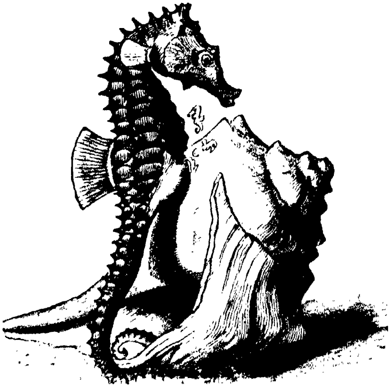

Fig. 424.—Sea-horse, male, with the young issuing from the brood-pouch.—After Lockwood.

Order 8. Plectognathi.—This group, represented by a few singular forms, such as the trunk-fish, file-fish, puffers, and sun-fish, is characterized by the union of the bones of the upper and especially the lower jaws. There are few vertebræ, the scales are often modified to form spines, and the ventral fins are usually absent. They are inhabitants of warm waters. The trunk-fish or box-fish, *Lactophrys trigonus* Poey, is a West Indian fish; one specimen has appeared at Holmes' Hole, Mass. The porcupine-fish (*Chilichthys turgidus* Gill) and smooth puffer (*Tetrodon lævigatus* Gill) and the spring box-fish (*Chilomycterus geometricus* Kaup) range from Cape Cod to Florida. The sun-fish (*Mola rotunda* Cuvier, Fig. 425) is, like the others of the order, a surface-swimmer. It is sometimes a metre or more in length, weighing five hundred pounds or more. Allied forms are *Orthagoriscus oblongus* (Fig. 426) and the globe-

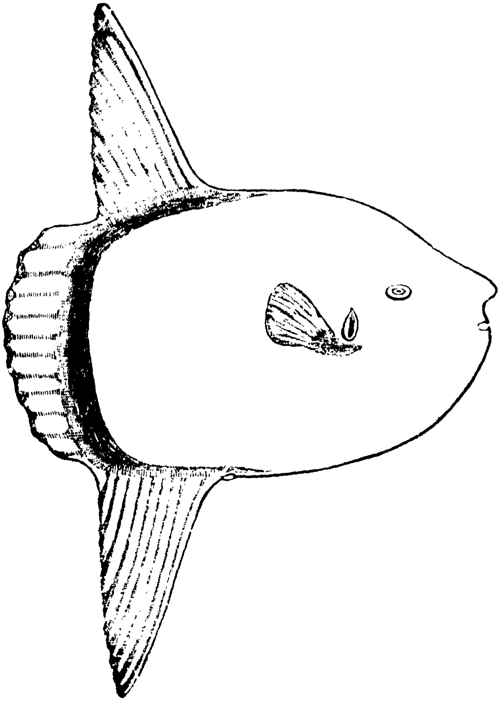

Fig. 425.—Sun-fish, *Mola rotunda*, one eighteenth natural size.—After Putnam.

fish, *Molacanthus Pallasii* (Fig. 427), which occur in the North Atlantic.

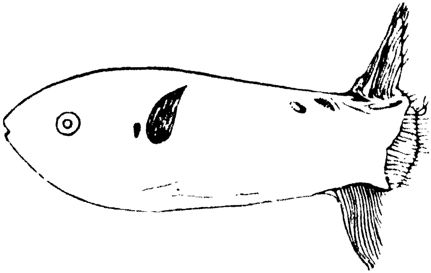

Fig. 426.—*Orthagoriscus oblongus*, young, natural size.—After Harting.

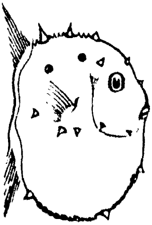

Fig. 427.—*Molacanthus Pallasii*, half grown, natural size.—After Putnam.

CLASS III.—PISCES.

Aquatic Vertebrates with a movable lower jaw, a cartilaginous or osseous skeleton, with paired and unpaired fins supported by fin rays; no sternum; usually covered with scales; breathing by gills. Heart with a single ventricle and auricle. Mostly oviparous.

Subclass I. *Elasmobranchii.*—Skeleton cartilaginous; skull without membrane bones, five to seven pairs of gill-sacs and gill-openings; no opercular bones; tail heterocercal; scales placoid; heart with a pulsating aortic bulb; optic nerves forming a chiasma; intestine with a spiral valve; both oviparous and viviparous.

Order 1. *Plagiostomi* (Selache, Lamna, Raia).

Order 2. *Holocephali* (Chimæra).

Subclass II. *Ganoidei.*—Skeleton cartilaginous or ossified; skull with plate-like membrane bones; one pair of gill-openings covered by opercular bones; skin usually with cycloid or ganoid scales; air-bladder with a pneumatic duct; embryos or young sometimes with external gills; chiasma of the optic nerves; intestine with a spiral valve; development, so far as known, much as in the sharks, and in some respects like the bony fishes; the living forms oviparous.

Order 1. *Chondroganoidei* (Acipenser).

Order 2. *Dipnoi* (Ceratodus, Lepidosiren)

Order 3. *Branchioganoidei* (Polypterus).

Order 4. *Hyoganoidei* (Lepidosteus, Amia).

Subclass III. *Teleostei.*—Skeleton bony; skull composed of numerous bones; optic nerves crossing each other; usually four pairs of gills, with several opercular bones; heart without a cone, but with an arterial bulb; intestine generally without a spiral valve; mostly oviparous.

Order 1. *Opisthomi* (Notacanthus).

Order 2. *Apodes* (Anguilla).

Order 3. *Nematognathi* (Amiurus).

Order 4. *Scyphophori* (Mormyrus).

Order 5. *Teleocephali* (Salmo, Perca, Gadus).

Order 6. *Pediculati* (Lophius).

Order 7. *Lophobranchii* (Hippocampus).

Order 8. *Plectognathi* (Tetrodon, Mola).

Laboratory Work.—Fishes should usually be dissected, except when large, under the water; small specimens can be pinned down to the bottom of cork- or wax-lined dissecting pans, and the more delicate parts worked out with fine scissors and knives. The brain and spinal cord can be dissected with ease, provided care be taken, with scalpel and scissors, as the bones covering them can be cut away by means of stout scissors and bone-pliers and fine surgical saws. Longitudinal sections will bring out the relations of the brain and beginnings of the nerves, and transverse sections of the tail may be made to show the disposition of the muscles. The skeleton may be prepared whole by removing the flesh carefully from alcoholic or partly macerated specimens. Disarticulated skeletons for study can be made by parboiling the fish and then separating the bones from the flesh. To study the circulation, careful injections should be made by the use of an injecting syringe, with wax, plaster of Paris, or vermilion as the injecting medium.

CLASS IV.—BATRACHIA (*Salamanders, Toads, and Frogs*).

General Characters of Batrachians.—We have had anticipations of the Batrachians or *Amphibia* in the Ganoids, especially the Dipnoan fishes, which it will be remembered approach the members of the present class in the lung-like nature of the air-bladder and in the presence of external gills in the young, as well as in the form of the skull, there being many bony parts in the skull which resemble similar parts in *Batrachia*. Indeed so close in some characters is the approximation of the fishes to the Batrachians, that the two classes have been placed in a series called *Ichthyopsida*. The Batrachians, however, differ essentially from the fishes in having the bones of the skull few, directly comparable with those of reptiles, birds, and mammals, and in being jointed to the vertebral column by two articular surfaces called *condyles*, the first vertebra, or atlas, having two corresponding articulating hollows. The limbs have the same number of subdivisions, with distinct leverage systems, as the higher Vertebrates, the bones composing them being closely homologous. True ribs now appear. Some have persistent external gills, and all have well-developed lungs. So that for the first time we have the coexistence of true limbs and lungs in animals which are air-breathing and move about freely on land, though from passing a part of their adult life in or about fresh water they are said to be amphibious. The skin is usually scaleless. The circulation is incompletely double, there being sometimes two auricles. Like fishes, they are cold-blooded. They are mostly oviparous, a few are viviparous, and nearly all undergo a metamorphosis.

To enter more into detail: The vertebræ of Batrachians are in the living *Proteus* and allies, and in the blind-worms (*Apoda*) biconcave; in the salamanders and in the Surinam toad (*Pipa*) and *Bombinator* they are concave behind, but in the toads and frogs generally they are for the most part concave in front, but vary in different parts of the spinal column, some of the same individuals being biconvex and others biconcave. While the vertebræ are numerous in the tailed forms, in the tailless toads and frogs there are but eleven, two in the coccyx, one in the sacrum, the remaining eight forming the rest of the column. In the frog, when the tail disappears, a long, spine-like piece (Fig. 428, *e*) called the *urostyle* is developed from the rudiments of a few vertebræ. In the extinct *Archegosaurus* the bodies of the vertebræ are but little ossified; in *Trimerorhachis* they are represented by the bony rings of three segments, while in allied

Labyrinthodonts such as *Rhiachitomus,* the vertebræ are ossified, but the centra consist of three pieces. In *Cricotus* there are two kinds of bodies, *centra* and *intercentra.* The ribs are rudimentary, except in the blind-worms (*Cæcilia*).

The skull is usually broad and flattened ; it differs from that of fishes in having no bones representing the operculum, suboperculum, interoperculum, or branchiostegal bones ; but a membrane bone probably homologous with the preoperculum is said to exist. The maxillary are usually and the premaxillary bones always present, usually armed with teeth ; no Batrachian possesses a complete basioccipital, supraoccipital, basisphenoid, alisphenoid, or presphenoid cartilage bone; while "the frog's skull is characterized by the development of a very singular cartilage bone, called by Cuvier the '*os-en ceinture,*' or girdle-bone." (Huxley.)

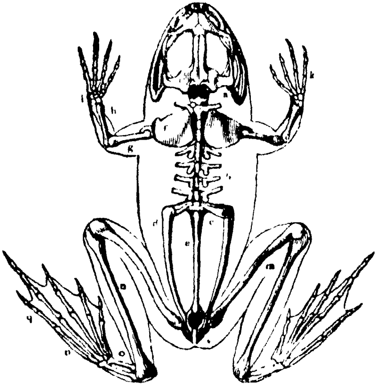

Fig. 428.—Skeleton of a Frog. *a*, skull ; *b*, vertebræ ; *c*, sacrum, and *e*, its continuation (urostyle); *f*, suprascapula ; *g*, humerus ; *h*, fore-arm bones ; *i*, wrist bones (carpals and meta-carpals) ; *d*, ilium ; *m*, thigh (femur) ; *n*, leg bone (ulna) : *o*, elongated first pair of ankle-bones (tarsals) ; *p*, *q*, foot bones or phalanges. —After Owen.

The embryonic cartilage persists in the lower jaw in adult Batrachians as in fishes, and bony parts are developed in connection with it which essentially correspond to those of fishes. (Gegenbaur.)

The suspensorium is immovably joined to the skull, and with it is connected the hyoidean arch. The branchial arches in the tailed forms persist in varying numbers, *i. e.*, from two to four, but are dropped in the toads and frogs. The skulls of certain Labyrinthodonts are roofed in by broad, flat bones, so that they bear a strong resemblance to certain Ganoids represented by the garpike, while Gegenbaur states that there are many bony parts in the skull of the Batrachians which resemble those in the Dipnoan fishes. The extinct *Archegosaurus* had in its larval life branchial arches, and in fact so close are the affinities of some Amphibians to the Ganoids that it is probable that both types have had a common origin; while on the other hand the bones of certain extinct scaly Labyrinthodonts have been regarded by some authors as reptiles; for example, the Carboniferous *Mastodonsaurus* was described as a reptile, but has been referred to the Amphibians by modern writers.

The sternum or breast-bone (Fig. 429, *s*) first appears in the Batrachians. The shoulder-girdle is in great part cartilaginous. In the toads and frogs (*Anura*) the fore limbs, the radius, and ulna, and in the hind limbs the tibia and fibula, grow together; there are four toes in the fore feet, and five toes in the hind feet. In the *Siren* the hind legs are wanting; in the congo-snakes (*Amphiuma*) the limbs are either two or three-toed.

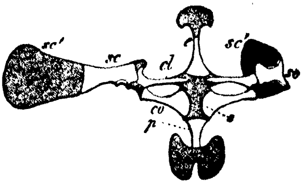

Fig. 429.—Sternum and shoulder-girdle of Frog (*Rana temporaria*). *p*, body of the sternum; *sc*, scapula; *sc'*, supra-scapula, *co*, coracoid-bone, fused in the middle line with its fellow of the opposite side (*s*); *cl*, clavicle; *e*, episternum. The extreme shaded double portion below *p* is the xiphisternum. The cartilaginous parts are shaded.—After Gegenbaur.

The teeth of modern Batrachians are conical or lobate, and microscopically are simple, while those of the extinct forms are mostly complicated by the labyrinthine infolding of the walls, as seen in microscopic sections; the teeth of many Ganoids have a similar, though much simpler structure. They are usually of the same size, and may be arranged on projecting portions of different bones of the mouth, *i.e.*, the premaxillary, maxillary, mandibular, vomerine, palatine, and pterygoid bones, as in fishes. In tadpoles and in *Siren* the jaw-bones are encased in horny beaks like those of turtles and birds. In many Labyrinthodonts two tusks were developed on the palate. The nasal canal is much as in the Dipnoan fish, the internal opening being situated in the Perennibranchiates just within the soft margin of the mouth. In the salamanders and frogs it is bordered with firmer parts of the jaw. The labyrinth of the ear is large, and the tympanum or drum of the ear is external, Am-

fishes, there are no salivary *glands*. The gills of Amphibians consist of two or three pairs of branched, fleshy appendages, which grow out from as many arches. While in the toad and frog the gills are small and remain but for a short time, in the larval salamanders, especially the axolotl (Fig. 430), the gills are still longer retained, while in the mud-puppy (*Necturus*) they persist throughout life.

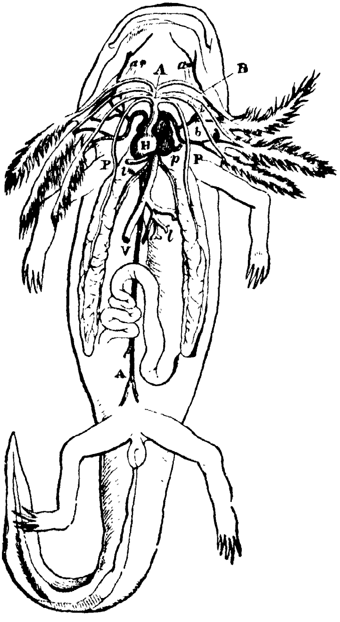

Fig. 430.—*Axolotl*, or larval Salamander, showing the gills, heart (*H*), aortic branches and lungs (*PA*). *P*, pulmonary arteries; *pp*, pulmonary veins; *A*, bulbus arteriosus from which the vascular arches (*B*) originate; *bb*, branchial vein; the lower *A*, vena cava; *V*, descending aorta.—From Gervais et Van Beneden.

The digestive canal is usually simple, straight, there being no enlargement forming a stomach; in other species, both tailless and tailed, the canal dilates into a stomach, which in the toad lies across the body-cavity. In tadpoles, which live on decaying vegetable matter, the digestive tract is very long and closely coiled (Fig. 431).

The lungs are long, slender sacs, much like those of the Dipnoan *Lepidosiren*, which extend backwards into the abdomen, as in the lizards and snakes, no diaphragm existing to confine them in a thoracic cavity. The larynx exists in a very rudimentary state, though the vocal powers of the toads and frogs are so highly developed. The trachea is short.

The heart has two auricles, the right one the larger, and a single ventricle; but in *Proteus* the auricles connect with each other, and in the salamanders there is a hole in the partition separating the auricles. There are also indications of a partition in the ventricle. Fig. 432 represents the circulatory organs of a tadpole, after the gills have become absorbed, and before the aortic arches are reduced in number.

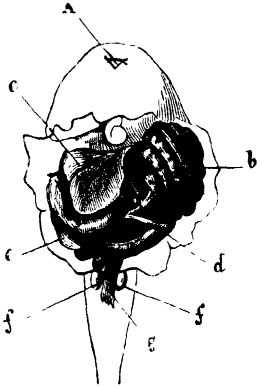

Fig. 431.—Mouth and digestive canal of a Tadpole. *A*, mouth; *b*, intestine coiled on itself; *c*, liver; *d*, hepatic duct; *e*, pancreas; *f*, rudimentary hind legs; *g*, rectum. —After Gervais and Van Beneden.

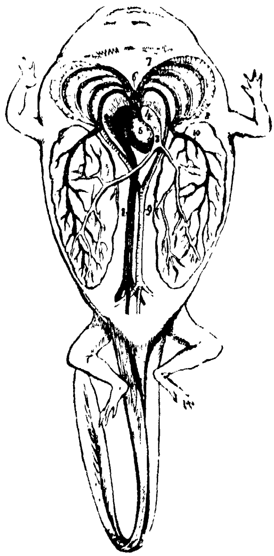

Fig. 432.—Tadpole of a Frog. 1, vena cava; 2, left auricle; 3, pulmonary vein and its origin in the two lungs; 4, left auricle; 5, ventricle; 6, arterial bulb; 7, branchial artery and its internal branches; 8, branchial veins; 9, aorta; 10, pulmonary artery and its subdivisions in the lungs.—After Gervais and Van Beneden.

The nervous system is much as in reptiles; but the optic lobes are rather small; the cerebrum is small. The kidneys are in many respects like those of fishes, especially sharks, as is the internal reproductive system. The ovaries are greatly enlarged during the breeding season. The sperm is usually passed to the kidney, and thence through the ureters out of the cloaca. The oviducts and ureters have a common outlet into the cloaca. In the salamanders the end of the oviduct serves as a uterus. There are also fat-bodies (Fig. 433) attached to the anterior end of the reproductive glands of the toads and frogs, the use of which is unknown. For a general idea of the structure of Amphibians the student should dissect a frog or toad in connection with the following description and accompanying illustration (Fig. 433), prepared by Dr. C. S. Minot.

The frog is one of the types of Vertebrates most valuable to the student, being readily obtained and easily dissected. The accompanying figure represents the anatomy of the spotted or leopard frog, *Rana halecina*, male.

The skin is smooth, having neither scales, feathers, nor hairs, and contains numerous microscopic glands, of which there are said to be two kinds—one having an acid, the other an alkaline secretion (L. Hermann). It is pigmented on the dorsal surface, but whitish underneath. The head is broad, triangular, with two large nasal openings in front, large and prominent eyes, two tympanic membranes formed by a part of the integument stretched across a hard ring, and an enormous mouth. The neck is short and not constricted. The body tapers slightly posteriorly, and has the opening of the cloaca upon the posterior end of its back. Each limb consists of the three divisions: in the front leg, *brachium*, *antebrachium*, and *manus* with four digits, of which the fourth is very much thickened in the *male;* the sexes may be distinguished by this mark. In the hind leg the three divisions are the *femur*, *crus*, and *pes*, with five long digits, between which the membranous web is stretched. If the web is examined in a living frog with a microscope, the circulation of the blood in the capillaries can be studied. The current of corpuscles and plasma is constant, and in a given vessel passes only in one direction; by following the stream backwards and forwards it will be found to issue from larger vessels, the arteries, and to enter into other and different vessels, the veins. The pigment corpuscles can also be seen in the web; they are branching bodies, capable of drawing in or expanding their processes, and they can be made to contract by an electrical shock from an induction

Slit open the skin along the median ventral line the whole length of the animal, turn the skin back, and then cut through the muscular walls of the abdomen, being careful not to injure the underlying organs. The viscera will then be exposed: the coiled intestine, the large liver, and in the female the sexual organs at either side; finally, posteriorly, the thin-walled bladder, *B*. The next step is to seize the posterior end of the sternum with a pair of forceps, lift it up, cut the fibres which run from its under surface, and cut with a pair of strong scissors along both sides of the sternum and around its anterior end, so as to remove it entirely. Underneath the sternum lies a thin-walled bag, the *pericardium*, enclosing the heart. On either side are the lungs.

To complete the preparation dissect out the intestine, by cutting through the mesentery; follow it to the stomach, which must be separated from the œsophagus and drawn aside together with the intestine, while the liver must be turned over to the right of the animal. The pericardium must be cut through and removed without injury to the heart; finally, the skin must be removed from the hind legs. If the dissection is of a male, it will then appear very much as in the figure.

The heart is conical in shape; its apex points backwards, and is formed by a single chamber, the ventricle, with thick muscular walls, from which springs on the *ventral* surface a little to the right the *truncus arteriosus* (*Ao*), which runs forward and divides into the two aortic arches. The base of the heart contains two chambers, the right and left auricles, the separation of which is not marked externally. A large vein (*V*) passes from the liver to the back of the heart, and there empties into a thin-walled sac, the *sinus venosus*, which also receives on either side a vein from above, the *venæ cavæ superiores*. The vein from the liver receives also the genital and renal veins, and is then called the *vena cava inferior*. As the heart continues to beat for many hours after a frog has been killed, if a fresh specimen is taken for dissection the rythmically alternating dilatations and contractions may be observed. The order of contraction is, 1st, the *sinus venosus ;* 2d, both auricles ; 3d, the ventricle ; 4th, the truncus.

In front of and below the heart may be seen the trachea, easily recognized by the hard rings of cartilage, and having the larynx just in front of the aortic arches and giving off two branches posteriorly, the bronchi, which run directly to the lungs. The trachea overlies the œsophagus, which terminates in the stomach (*St*). On either side of the trachea lies a thyroid gland (*th*).

The liver (*Li*) is a large brown mass, composed of two lobes, of which the left is the larger, and subdivided into two. Between the two lobes lies a small greenish sac, the gall-bladder (*b*). The liver receives a large vein (*pv*) from the kidneys ; this is the portal vein, which distributes to the liver the blood which has already once passed through the capillaries of the other abdominal viscera. The hepatic vein takes the blood from the liver directly to the heart.

The stomach (*St*), when *in situ,* lies on the left side of the abdominal cavity, its œsophageal end being the largest ; it leads directly into the intestine, which is of uniform width throughout, but terminates in the dilated rectum (*R*), which in its turn opens into the cloaca. To the ventral surface of the cloaca is appended the bladder (*B*). Imbedded in the mesentery near the commencement of the intestine is a pale compact mass, the pancreas, not represented in the figure, and a little farther from the stomach a small round dark body, the spleen (*Sp*).

The kidneys (*Ki*) are two elongated deep red bodies, upon which lie a number of yellow spots, the *adrenal glands.* The renal ducts arise from the outer and anterior portion of the kidneys and then run backwards as two white convoluted canals (*vd*), at first very narrow, then widening, and ending with a dilatation immediately before they open into the cloaca. These ducts serve at once as *uretèrs* and *vasa deferentia.* In front of the kidneys lie a pair of oval yellow bodies, the testes (*Te*). The female has both ureter and oviduct. The ovary varies greatly in size and appearance according to its condition. The oviduct is a very long convoluted tube running from the pericardium backwards to the cloaca, where it opens just in front of the ureter. At the season of reproduction the oviduct is found very much distended with ova. Its anterior end has a ciliated opening into the body-cavity. In the neighborhood of the sexual glands lies the fat-body (*f*).

The lungs (*lu*) are two large sacs with very elastic walls, richly supplied with blood-vessels. These vessels spring from the pulmonary artery. From each division of the *truncus arteriosus* are given off four branches (Fig. 433, II). The first is the pulmonary aorta (*Pa*), which also gives off a large cutaneous branch ; the second, the true aortic arch (*Ao*), which, curving backwards, unites with its fellow just in front of the kidneys and below the spinal column, to form the descending aorta ; the third (*cr*), the carotid artery, running to the head, and bearing at its origin the singular carotid gland (*cg*) ; the fourth, the lingual artery. The blood is returned from the lungs by two veins, which empty into the left auricle.

The space of the lower jaw is covered over by a thin transverse muscle (*My*), the mylohyoid. On either side behind the posterior edge of this muscle lies a croaking bag or air-sac (*S*). In the mouth are to be observed, 1st, the muscular tongue, attached by its anterior end to the lower jaw, and forked posteriorly ; 2d, the openings of the nasal cavities ; 3d, the *recessus Eustachii*, lying further back, and leading into the tympanic cavity ; 4th, the opening of the œsophagus ; and 5th, the slit-like epiglottis.

The muscles are best dissected in alcoholic specimens. The muscles of the hind limbs are as follows : On the ventral surface, the cut ends of the *recti abdominis* (*r. ab.*) ; *on the ventral surface*, 1, of the thigh, outwardly *musculus vastus internus* (*mvi*), the *adductor longus* (*a*), the *sartorius* (*ms*), *adductor magnus* (*a″*), *rectus internus minor* (*ri″*) ; the *rectus internus major* (*ri′*) ; a small part of the *adductor brevis* can be seen close to the pubis between the adductor magnus and the rectus internus major ; underneath the rectus internus major lies the long and the *semitendinosus* with two heads ; 2, of the leg (*crus*) *gastrocnemius* (*g*), and between that muscle and the bone the *tibialis posticus ;*

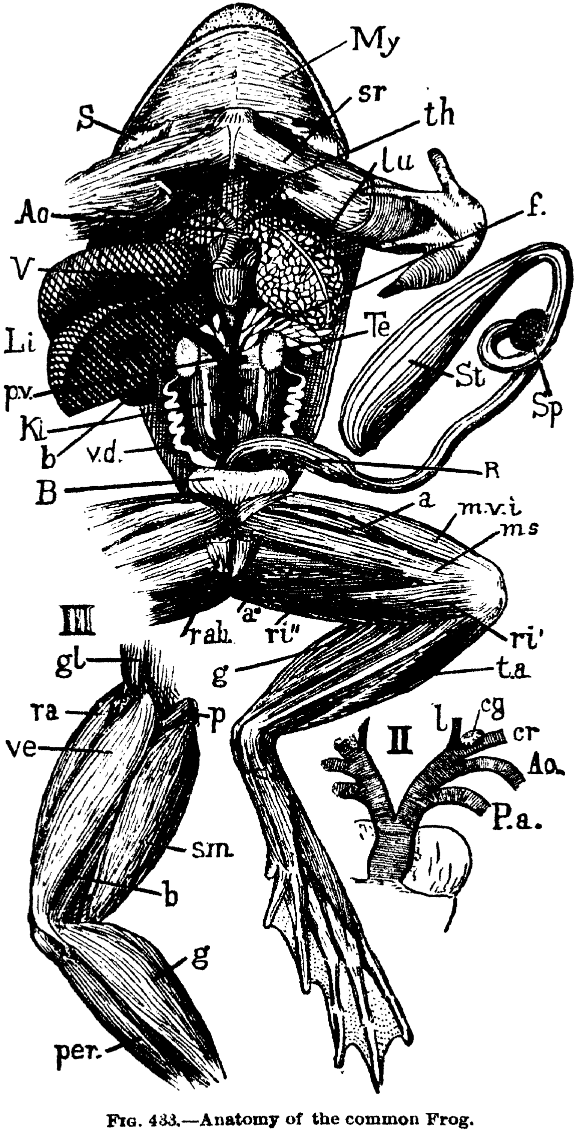

FIG. 433.—Anatomy of the common Frog.

in front is the *tibialis anticus* (*ta*). *On the dorsal surface of the thigh* (Fig. 433, III) the *glutæus* (*gl*), the *pyriformis* (*p*), the *rectus anticus femorus* (*ra*), the *vastus externus* (*ve*), the *biceps* (*b*), the *semimembranosus* (*sm*), lying deep between the biceps and semimembranosus are seen the femoral vessels and sciatic nerve; the rectus anticus, vastus internus and externus are known collectively as the *triceps femoris;* in the leg the *gastrocnemius* (*g*) and *peronæus* (*p*).

The sympathetic nerves can be seen as two cords, one on either side of the vertebral column. The spinal nerves can be seen as white threads on the dorsal surface of the body-cavity. The brain (Fig. 373) may be dissected out by opening the skull from above. The olfactory lobes of frogs and toads are fused together, but separate in the tailed Batrachia. The seventh, eighth, and ninth spinal nerves unite to form the very large sciatic trunk; the intercommunications of these nerves form the lumbar plexus; while the second and third spinal nerves form the brachial plexus from which arises the brachial nerve. (C. S. Minot.)

Certain glands in the skin of some Batrachians secrete a corrosive, or as in the European *Salamandra maculosa*, a narcotic poison, which is poisonous to small animals. The toads secrete in the parotid glands a bad-smelling fluid, which applied to tender skins produces erysipelas. Lacerda states that the poison of the Brazilian *Bufo ictericus* is a milky humor from the glands on the sides of the neck. The action of the poison is less fatal to small animals than that of the European toad; it gives a slight acid reaction and is not soluble in alcohol, while that of the European toad is.

Like fishes, the Batrachians assume high colors during the breeding season. The males of the newts at this time

Fig. 433.—Anatomy of common Frog. *My*, mylohyoid; *sr*, sternoradials; *th*, thyroid; *lu*, lungs; *f*, fat-body; *Te*, testis; *St*, stomach; *Sp*, spleen; *R*, rectum; *a*, adductor longus; *mri*, vastus internus; *ms*, sartorius; *ri′*, rectus internus major; *ta*, tibialis anticus; *g*, gastrocnemius; *ri″*, rectus internus minor; *a″*, adductor magnus; *rab*, rectus abdominalis; *B*, bladder; *vd*, vas deferens; *b*, gall-bladder; *Ki*, kidney; *pv*, portal vein; *Li*, liver; *V*, vena cava inferior; *Ao*, aorta; *S*, vocal sac, or croaking-bag.

II. Origin of the arterial trunks. *l*, arteria ingnalis; *cg*, carotid gland, which is merely a *rete mirabile; cr*, carotid artery; *Ao*. aortic arch; *Pa*, pulmonary artery.

III. Dorsal view of muscles of hind leg. *gl*, glutæus; *ra*, rectus anterior; *p*, pyriformis; *ve*, vastus externus; *sm*, semi-membranosus; *b*, biceps; *g*, gastrocnemius; *per*, peronæus.—Drawn by C. S. Minot.

acquire the dorsal crest and a broader tail-fin, while in some species prehensile claws are temporarily developed on the fore legs of the male. The males of the *Anura* (toads and frogs) are musical, the females being comparatively silent: the vocal organs of the male are more developed than in the females, and in the edible frog (*Rana esculenta*) large sacs for producing a greater volume of sound stand out on each side of the head of the males. Among the few viviparous Batrachians known is an Alpine European *Salamandra* (*S. atra*) which brings forth its young alive.

It is common to find tadpoles in the winter in ponds, which have been retarded in their metamorphosis, and by artificial means this retardation may be greatly increased. For example, Wyman is said to have kept tadpoles of the bull-frog for seven years in a cellar.

Unlike the higher Vertebrates the segmentation of the egg in the Amphibia is total, the process beginning usually about *three hours after impregnation* in the frog, and lasting twenty-four hours. The primitive streak, the notochord and nervous system then arise as in other craniated Vertebrates. After the appearance of the branchial arches, the gills begin to bud out from them, finally forming the larger gills of the tadpole. Unlike young fishes, the yolk is entirely absorbed before the tadpole leaves the egg. In warm climates the tadpoles hatch in four or five days after the eggs are laid. When hatched the tadpole is not so well developed as in most young fishes. The digestive canal at first is simple and straight. Afterwards it becomes remarkably long and coiled in a close spiral. The mouth is small (Fig. 434, *A*), with no tongue and only horny toothless jaws. The vertebræ of the tadpole are biconcave as in fishes, afterwards becoming converted into cup-and-ball joints.

The accompanying figures represent the external changes of the toad from the time it is hatched until the form of the adult is attained. The tadpoles of our American toad are smaller and blacker in all stages of growth than those of the frog. The tadpole is at first without any limbs (Fig. 434 *A*), and with two pairs of gills; soon the hinder legs bud out. After this stage (*B*) is reached, the body begins to diminish in size. The next important change is the growth of the front legs and the partial disappearance of the tail (*C*), while very small toads (*D* and *E*), during midsummer, may be found on the edges of the pools in which some of the nearly tailless tadpoles may be seen swimming about. It is three years before the Amphibia are capable of breeding. In the newts (*Triton*) the gills are in three pairs, larger and more complex than in the frog; the fore limbs are the first to grow out, and the gills persist long after the hind limbs are developed. In the newts we have the larval state of the toads and frogs persistent; thus the successive steps in the development of the individual frog is an epitome of the evolution of the typical forms of the class to which it belongs.

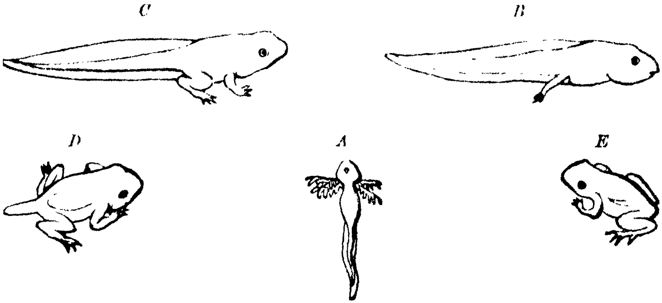

Fig. 434.—Metamorphosis of the Toad.—After Owen; from Tenney's Zoology.

In certain Batrachians as the Alpine salamander, the Surinam toad (*Pipa*) and the *Hylodes* of Guadaloupe in the West Indies, the metamorphosis is suppressed, development being direct; though the young have gills, they do not lead an aquatic life. In the axolotl there is a premature development of the reproductive organs, the larvæ as well as the adults laying fertile eggs.

The Batrachians are inhabitants of the warmer and temperate zones. Frogs extend into the arctic circle. The *Amblystoma mavortium* breeds at an altitude of about 8000 feet in the Rocky Mountains. *Rana septentrionalis* Baird extends to Okak, Northern Labrador, where the climate is as extreme as that of Southern Greenland; frogs have also been observed at the Yukon River in lat. 60° N., but the climate there is milder than that of Labrador. The common toad and a salamander (*Plethodon glutinosa* Baird ?) extend to Southern Labrador.

Nearly 700 species of existing Batrachians are known, 101 of which are North American, and about 100 fossil forms have been described.

There are five orders of Batrachians, Professor Cope's classification being adopted in this work. Those Batrachians with persistent gills are sometimes called *Perennibranchiates*.

Order 1. *Trachystomata.*—The sirens have a long eel-like body, with persistent gills; there is no pelvis or hind limbs, and the weak, small fore legs are four or three-toed. The great siren, *Siren lacertina* Linn., is sometimes a metre in length, and has four toes in the fore leg; it lives in swamps and bayous from North Carolina and Southern Illinois to the Gulf of Mexico. A small siren with three toes and small gills is *Pseudobranchus striatus* Le Conte. It occurs in Georgia.

Order 2. *Proteida.*—This group is represented by the *Proteus* of Austrian caves and the mud-puppy (*Necturus*) of the United States. These Batrachians have bushy gills, with gill-openings and well-developed teeth. In *Proteus*, which is blind, there are three toes in the fore feet and two in the hinder pair. In the mud-puppy, *Necturus* (formerly Menobranchus) *lateralis* Baird, each foot is four-toed. The head and body are broad and flat, brown with darker spots. It has small eyes and is about half a metre (from 8 inches to 2 feet) in length. It inhabits the Mississippi Valley, extending eastward into the lakes of Central New York. The *Proteus* as well as the mud-puppy lay eggs.

Order 3. *Urodela.*—The tailed Batrachians or Salamanders rarely have persistent gills, these organs being larval or transitory; the body is still long and fish-like, the tail sometimes with a caudal fin-like expansion as in the newts, but is usually rounded, and the four legs are always present. With only one or two viviparous exceptions, most of them lay eggs in the water. The eggs of *Triton* are laid singly on submerged leaves; those of *Notophthalmus viridescens* are laid singly on leaves of Myriophyllum, which adhere to the glutinous egg, concealing it. (Cope.) Those of *Desmognathus* are laid connected by a thread both on land and in water. The common land salamander, or *Plethodon erythronotum* Baird, lays its eggs in summer in packets under damp stones, leaves, etc. ; the young are born with gills, as is the case with the viviparous *Salamandra atra* of the Alps. The possession of gills by land salamanders, which have no use for them, and which consequently drop off in a few days, leads us justly to infer that the land salamanders are the descendants of those which had aquatic larvæ.

The lowest form of this order is the aquatic Congo-snake or *Amphiuma means* Linn., in which the body is large, very long, round and slender, with small rudimentary two-toed limbs ; there are no gills, though spiracles survive. It lives in swamps and sluggish streams of the Southern States.

A step higher in the Urodelous scale is the *Menopoma*, which is still aquatic, with persistent gills, but the body and feet are as in the true salamanders. The *Menopoma Alleghaniense* Harlan, called the hellbender or big water lizard, is about half a metre (1½–2 feet) in length, and inhabits the Mississippi Valley. Allied to the Amphiuma is the gigantic Japanese salamander, *Cryptobranchus Japonicus* Van der Hoeven, which is a metre in length. Allied in size to this form was the great fossil salamander of the German Tertiary formation, *Andrias Scheuchzeri*, the *homo diluvii testis* of Scheuchzer, thought by this author to be a fossil man.

In the true salamanders the body is still tailed, the eyes are rather large ; there are no spiracles ; they breathe exclusively by their lungs, except what respiration is carried on by the skin.

The genus *Amblystoma* comprises our largest salamanders ; they are terrestrial when adult, living in damp places and feeding on insects. The larvæ retain their gills to a period when they are as large or even larger than the parent. The most interesting of all the salamanders is the *Amblystoma mavortium*, whose larva is called the axolotl, and was originally described as a perennibranchiate amphibian under the name of *Siredon lichenoides* Baird. This larva is larger than the adult, terrestrial form, sometimes being about a third of a metre (12 inches) in length, the adult being twenty centimetres (8 inches) long, forming an example of what occurs in the Amphibians and also certain insects, of the excess in size and bulk of the larva over the more condensed adult form. This law is also strikingly observed in the *Pseudes* (Fig. 437). This fact of prematuritive, accelerated, vegetative development of the larva over the adult is an epitome of what has happened in the life of this and other classes of animals. The fossil, earliest representatives of the Amphibians, as we shall see farther on, were enormous, monstrous, larval, premature forms compared with their descendants. The same law holds good in certain groups of Crustacea (trilobites), insects, fishes, reptiles and mammals.

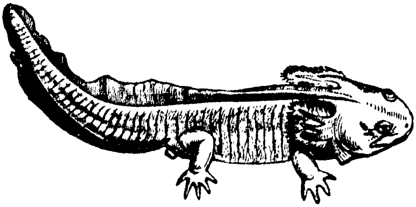
Fig. 435.—Siredon or larval Salamander.—From Tenney's Zoology.

The axolotl or siredon abounds in the lakes of the Rocky Mountain plateau from Montana to Mexico, from an altitude of 4000 to 8000 or 9000 feet; the Mexican axolotl being of a different species, though closely allied to that of Colorado, Utah and Wyoming. The Mexicans use the animal as food. Late in the summer the siredons at Como Lake, Wyoming, where we have observed them, transform in large numbers into the adult stage, leaving the water and hiding under sticks, etc., on land. Still larger numbers remain in the lake, and breed there, as I have received the eggs from Mr. William Carlin, of Como. Thousands of the fully-grown siredons are washed ashore in the spring when the ice melts. They do not appear at the surface of the lake until the last of June, and disappear out of sight early in September. The eggs are laid in masses, and are 2 millimetres in diameter. Mr. F. F. Hubbell has observed in Como Lake, July 23d, young siredons four to six centimetres (1½–2½ inches) in length, and September 3d specimens eight centimetres (3 inches) long. In Utah, Mr. J. L. Barfoot raised in 1875 several adults from the larva, and I have been told that siredons in the mountains among the miners' camps near Salt Lake City leave the water and transform. It thus appears that in the elevated plateaus* as well as at the sea-coast, some siredons transform while others do not. Mexican siredons have for a number of years been bred from eggs in the aquaria of Europe, laying eggs the second year.

The change from the larva to the adult consists, as we have observed, in the absorption of the gills, which disappear in about four days; meanwhile the tail-fins begin to be absorbed, the costal grooves become marked, the head grows smaller, the eyes larger, more protuberant, and the third day after the gills begin to be absorbed the creature becomes dark, spotted, and very active and restless, leaving the water. Their metamorphosis may be greatly retarded and possibly wholly checked by keeping them in deep water. The internal changes in the bones of the head and in the teeth are very marked, according to Dumeril.

Experiments made in Europe show that the legs and tail of the axolotl, as of other larval salamanders, may be reproduced. We cut off a leg of an axolotl the first of November; it was fully reproduced, though of smaller size than the others, a month later. The tail, according to Mr. L. A. Lee, if partly removed, will grow out again as perfect as ever, vertebræ and all.

The Tritons or water-newts, represented by our common, pretty spotted newt, *Diemyctylus viridescens* Rafinesque, are also known in Europe to become sexually mature in the larval state when the gills are still present, as has been observed by three different naturalists. The female larva of *Lissotriton punctatus* has been known to lay eggs.

Order 4. *Gymnophiona.*—The blind snake with its several allies is the representative of this small but interesting order.

*** It has been stated by De Saussure, Cope, Marsh, and more recently by Weismann, that the siredon does not change in its native elevated home. No naturalist has seen the Mexican siredon transform into an Amblystoma, but as it does so in abundance in Wyoming and Utah, it probably transforms in Mexico. (The adult Mexican form has recently been found, and is at the Smithsonian Institution.)**

The body is snake-like, being long and cylindrical; there are no feet and no tail, the vent being situated at the blunt end of the body. The skin is smooth externally, with scales embedded in it, but with scale-like transverse wrinkles. The eyes are minute, covered by the skin. The species inhabit the tropics of South America, Java, Ceylon, and live like earthworms in holes in the damp earth, feeding on insect larvæ. They are large, growing several feet in length. *Cœcilia lumbricoides* Daudin inhabits South America. *Cœcilia compressicauda* of Surinam is viviparous, the young being born in water and possessing external gills which are leaf-shaped sacs resting against the sides of the body; when the animal leaves the water they are absorbed, leaving a scar. (Peters.) *Siphonops Mexicana* Dumeril and Bibron, is a Mexican form.

Order 5. *Stegocephala.*—Here belong an order of extinct Batrachians, with three suborders, *Labyrinthodontia, Ganocephala*, and *Microsauria* (Cope). In these forms the skulls were either somewhat like those of the frogs, or the crania were roofed in by solid flat bones, similar to those of ganoid fishes. The vertebræ were biconcave. The limbs of the Labyrinthodonts were like those of the tailed Batrachians, of small size and weak, compared with the great size of the body. Von Meyer states that *Archegosaurus* possessed branchial arches when young, and that probably other Labyrinthodonts resembled it in this respect. It had paddles instead of feet, the head had an armor of plates, and the body was covered with overlapping ganoid scales. It had teeth like those of ganoid fishes; it had a notochord, the bodies of the vertebræ being neither bony nor cartilaginous. Owen regards it as combining the characters of the perennibranchiate Amphibians and the Ganoid fishes. It was a little over a metre (3½ feet) in length. It is a representative of the suborder *Ganocephala*.

While the older text-books in the restorations of *Labyrinthodon* represented it as like a toad, with large legs and tailess, it is now known that some of the gigantic predecessors of the salamanders and tritons had long tails, while others had long, cylindrical, snake-like bodies. Unlike existing Batrachians, their fossil ancestors had an armor of large breast-plates, with smaller scales on the under and hinder part of the body.

But the largest forms were the true Labyrinthodonts represented in the Carboniferous rocks of this country by *Baphetes*, and in Europe by *Anthracosaurus*, *Zygosaurus*, and in the Permian beds of Texas by *Eryops*. Labyrinthodonts also abounded in the Triassic Period, and forms like the European *Labyrinthodon* or *Mastodontosaurus* must have been colossal in size. Footprints occur in the Subcarboniferous rocks of this country which indicate forms still larger than any yet discovered in the Old World. A large number (thirty-four species, referable to seventeen genera) of medium-sized Labyrinthodonts have been described from the coal measures of Ohio by Cope which were characterized by their long, limbless, snake-like bodies and pointed heads, forming a still more decided approach to the Ganoids. This was the lowest group of *Stegocephala*, called *Microsauria* by Dawson.

Thus we have in these Labyrinthodonts synthetic or annectant forms, which connect the fishes with the Amphibians, and on the other hand point to the incoming of the reptiles. They were thus prematuritive, larval forms, which in certain characters anticipated the coming of a higher type of Vertebrate. The reptiles were ushered in during the Permian Period, the rocks of this age immediately overlying the coal measures, though it should be stated that there are obscure traces of reptiles in the Carboniferous rocks. It is not improbable that evidence will be found to substantiate the impression that the reptiles, together with but independently of the Amphibians, branched off from the Ganoid fishes, or from extinct forms related to them.

Order 6. *Anura.*—The toads and frogs represent this order, which comprises tailless Batrachians, with the four limbs present, the toes being very long (due to the great length of the calcaneus and astragalus), while the body is short and broad, the skin soft and smooth, scaleless, though small plates are sometimes embedded in it. The lower jaw is usually toothless. The larvæ are called tadpoles, and represent the adult form of the Perennibranchiates. The external gills are in the adult replaced by shorter internal ones.

Among the lower frogs or arciferous *Anura* of Cope, *i.e.*, those with the acromial and corocoid bones divergent and connected by distinct cartilage plates, are certain forms, as *Alytes*, *Pelobates*, and *Pelodytes*, whose breeding habits are peculiar and interesting. The eggs of *Pelodytes* are deposited in small clusters in the water, those of *Pelobates* in a thick loop. The male of the European *Alytes obstetricans* winds a string of eggs which it takes from the female, and goes into the water, where it remains until the young (which have no gills) are hatched. The American *Scaphiopus*, or spade-footed toad, is not known to have this obstetrical habit. This singular toad appears suddenly and in great numbers. It remains but a day or two in the water, where it lays its eggs in bunches from one to three inches in diameter. The tadpoles hatch in about six days after the eggs are laid ; their growth is rapid, the young toads leaving the water in two or three weeks. The croaking of this toad is harsh, peculiar, and need not be confounded with that of any other species. (Putnam.) As the spade-footed toads are rarely seen, it is possible that they burrow in the soil, like the European *Alytes*. Another peculiarity in the reproductive habits of *Alytes*, *Pelobates*, *Cultripes*, and *Pelodytes* is that they spawn at two seasons instead of one, and that their larvæ, like *Pseudes* (Fig. 437), attain a greater size than those of other frogs before completing their metamorphosis. (Cope.)

Among the tree-toads, *Polypedates* of tropical Western Africa, contrary to the usual habits of frogs, deposits its eggs in a mass of jelly attached to the leaves of trees which border the shore overhanging a pond. On the arrival of the rainy season, the eggs become washed into the pond below, where the male frog fertilizes them. Our common piping tree-toad (*Hyla Pickeringii* Le Conte), about the middle of April, in the neighborhood of Boston, attaches her eggs simply to aquatic plants. The young are hatched in about twelve days.

As an example of a suppressed metamorphosis, due apparently to a radical difference in the physical environment of the animal, may be cited the case of a tree-toad in the island of Guadaloupe. There are no marshes on this island, consequently in a species of *Hylodes* the development of the young is direct; they hatch from the eggs which are laid under moist leaves, without tails, and are otherwise, except in size, like the adults. On the other hand, a tree-toad of the island of Martinique (*Hylodes Martinicensis*, Fig. 436) has tadpoles, which it carries on its back. The female of *Nototrema marsupiatum* Dumeril and Bibron, of the Andes, has a marsupium or sac on its back in which the young are carried. The *Notodelphys* of South America has similar habits; for example, the female *Opisthodelphys* (*Notodelphys*) *ovifera* has a dorsal sac a centimetre deep in which the eggs are carried. In the young of this and of *Gastrotheca* also of Central America, Peters found traces of external gills. The *Pipa*, or Surinam toad (*Pipa Americana* Laurent), which has no tongue, neither teeth in the upper jaw, has similar breeding habits. In this interesting toad the young, according to Prof. Wyman, are provided with small gills, which, however, are of no use to them, as the tadpoles do not enter the water, but are carried about in cavities on the back. The eggs are placed by the male on the back of the female, where they are fertilized. The female then enters the water; the skin thickens, rises up around each egg and forms a marsupial sac or cell. The young pass through their metamorphosis in the sacs, having tails and rudimentary gills; these are absorbed before they leave their cells, the limbs develop, and the young pass out in the form of the adult.

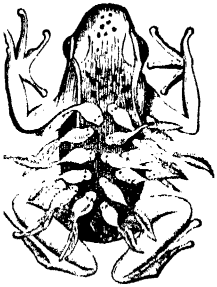

Fig. 436.—The Martinique Tree-toad carrying the young on its back.

The toad (*Bufo lentiginosus* Shaw) is exceedingly useful as a destroyer of noxious insects. It is nocturnal in its habits; is harmless, and can be taken up with impunity, though it

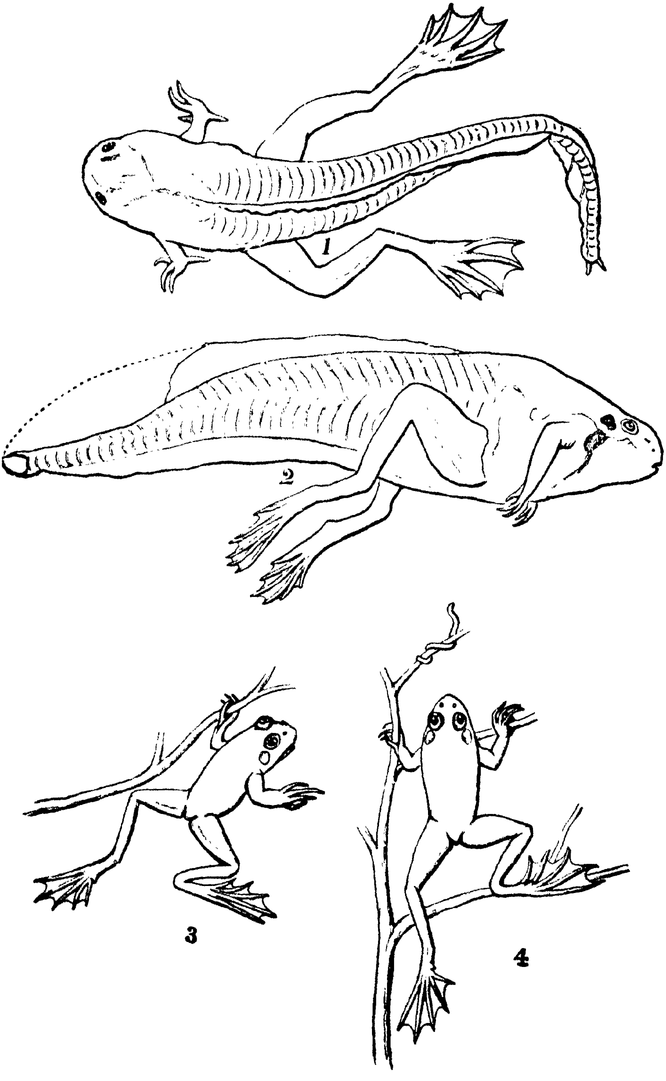

Fig. 437.—The Paradoxical Frog. 1, 2, larva, nearly of natural size; 3, 4, *Pseudes minuta*, natural size.—1, 2, after Pizarro; 3, 4, after Garman.—From the *American*

gives out an irritant acrid fluid from the skin, which may poison the eyelids. In New England toads begin to make their peculiar low trilling notes from the middle to the 20th of April; from the latter date until the first of June they lay their eggs in long double strings, and the tadpoles (Fig. 434) are usually hatched in about ten days after the eggs are deposited. (Putnam.)

The paradoxical frog of South America (*Pseudes paradoxa* Wagler, Fig. 437, 1, 2, the larva) is remarkable from the fact that the larva is larger than the adult. 3 and 4 represent another species of *Pseudes* (*P. minuta*).

The highest genus of the *Anura* is *Rana*, of which there are numerous species, our American forms being the bullfrog (*Rana pipiens* Linn.), the *Rana palustris* Le Conte, or pickerel-frog, and the marsh-frog (*Rana halecina* Kalm). They lay their eggs in masses in the water in April, May, and the early part of June, according to the latitude.

While most frogs are eaten by birds, and in such cases are preserved from extinction by their nocturnal habits and their protective resemblance to the herbage and the bark and leaves of trees, Thomas Belt records the case of a little Nicaraguan frog which is very abundant in damp woods, and "hops about in the daytime, dressed in a bright livery of red and blue." Its immunity from destruction is due to the fact that ducks and fowl could not be induced to eat it, owing to its unpleasant taste, the same reason inducing birds to reject certain bright-colored caterpillars, which are distasteful to them.

CLASS IV.—BATRACHIA.

Amphibious Vertebrates, with gills in certain adult aquatic forms, all breathing air by lungs; the skin of existing species naked; with true limbs like those of higher Vertebrates; skull with two occipital condyles; heart with two auricles and one ventricle. Mostly oviparous; a distinct metamorphosis.

***Order* 1. *Trachystomata*.**—**Body long, eel-like, with persistent gills; no pelvic bones or hind limbs; no maxillary bone. (Siren.)**

Order 2. *Proteida.*—Body flattened, with persistent gills, and gill-openings; a maxillary bone. (Proteus, Necturus.)

Order 3. *Urodela.*—No persistent gills, body with a tail; no gill-openings except in Menopoma and Amphiuma. (Salamandra.)

Order 4. *Gymnophiona.*—Body snake-like, no feet; no tail; young with gill-openings, but no gills. (Cœcilia.)

Order 5. *Stegocephala.*—Extinct forms; the temples with a bony roof; often large; either snake-like, without limbs, or with paddle-like limbs, or with four legs; teeth with or without labyrinthine structure. (Archegosaurus, Labyrinthodon.)

Order 6. *Anura.*—Body short, tailless, with four limbs; toes very long; leapers; larvæ tailed. (Bufo, Rana.)

Laboratory Work.—The student should carefully follow, with a specimen in hand, the description of the structure of the frog, aided by the figure; then should make a skeleton of the same species. These studies should then be followed by a close comparison with the structure of a mud-puppy and of a salamander—the osteology and anatomy of the softer parts receiving equal attention. The breeding habits of the Batrachians may be studied by confining them in jars or aquaria. The embryology can best be studied by hardened stained sections of the eggs.

CLASS V.—REPTILIA (*Lizards, Snakes, Turtles, and Crocodiles*).

General Characters of Reptiles.—In the members of the present class we have a still farther elaboration of a type of structure which first appears in the Batrachians, with the addition of features, which on the other hand are wrought out in a more detailed manner in the birds, so much so that while the fishes and Batrachians form one series (*Icthyopsida*), a study of different fossil reptiles, especially the bird-like reptiles (Dinosaurs and Pterosaurs), which clearly connect the birds with the reptiles, shows that the two latter groups should be united into a series called *Sauropsida.* Thus no one class of Vertebrates stands alone by itself; every year fresh researches by palæontologists, and the re-examinations of living Vertebrates, especially as to their embryonic history, proves that no single class, not even a type so well circumscribed as the modern birds, is without links forming genetic bonds allying them all together. In fact, the different classes of Vertebrates, as well as of other branches of the animal kingdom, form an ascending series, from the more generalized, though not always simple forms (numerous groups comprising synthetic types), to those which are more specialized, *i.e.*, in which separate organs or groups of organs are elaborated and worked out in great detail. This is the tendency all through nature, and were Cuvier himself now living, and were he to examine the facts revealed since his death, he would, as many others in advanced life have done, cast aside the limited, analytical notions of the past, based as they were on fragmentary evidence, and adopt the more philosophical principles of classification, based on sciences that were in embryo thirty or forty years since. These reflections have great force in the study of a class like the reptiles where there are a larger number (five) of extinct, than of living (four) orders, and where the fossil types were of a more general, almost embryonic type, and consequently gigantic and ill-shapen, showing a tendency to extremes or prematurity in development rather than to an equality in and maturity of the whole organization compared with their descendants. A high degree of specialization of type tends nearly always in living beings, plants as well as animals, to a condensation and higher grade of form. These animals also have given a name to the Age of Reptiles, the middle or Mesozoic age of the world, when they were the dominant type of life.

The essential characters of reptiles are the following: As regards the skeleton, the bodies of the vertebræ vary in being either biconcave, concave in front, concave behind, or flat at each end; the cup-and-ball vertebræ are most common, forming a strong and flexible joint well fitted for general motion. The ribs are well developed, the sternum is rhomboidal; there are usually, if not always, more than three toes. The body is covered with scales; the blood is cold, the heart has in the crocodiles, the highest order, four chambers; two or more aortic branches persist, and certain membranes, called an amnion and allantois, envelop the embryo.

The vertebral column is now more distinctly marked off than in the Batrachians; a cervical and lumbar region being indicated in most reptiles except the snakes and turtles. Well-marked ribs exist in nearly all the vertebræ of the trunk, except in the turtles, where the so-called ribs are possibly, according to Gegenbaur, modified transverse processes.

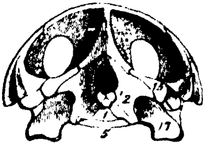

Fig. 438.—Skull of a Turtle seen from behind, 1, basi occipital; 2, exoccipital; 3, supraoccipital; 5, basisphenoid; 15, prootic (petrosal); 17, quadrate.—After

The skull of reptiles is much more like that of birds than of Amphibians. There is a single occipital condyle, and the lower jaw is articulated by the quadrate-bone to the base of the skull. The primitive skull, or that part immediately enclosing the brain, has an incomplete roof, but still is more bony than in Batrachians; while owing to the great size of the bones developed originally in and from the palato-quadrate cartilage, but a small part of the true skull is to be seen. The parts forming the hyoid suspensorium in fishes (hyomandibular and symplectic bones) are, as in the Batrachians, entirely separate from the skull.

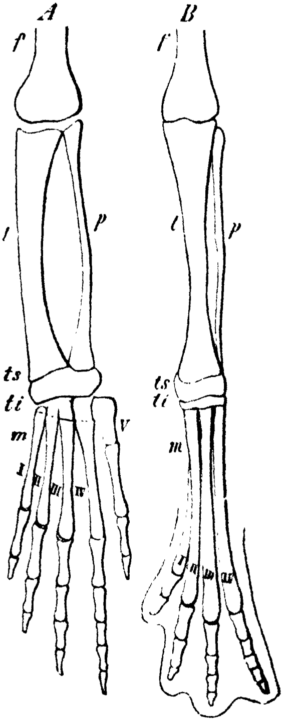

Fig. 439.—Bones of the foot of a Reptile (lizard) *A*, and an embryo bird, *B*. *f*, femur; *t*, tibia; *p*, fibula, *ts*, upper, *ti*, lower pieces of the tarsus; *m*, metatarsus; *I*-*V*, metatarsalia of the toes.

While the limbs are, as a rule, absent in the snakes, the fore legs always wanting, in a few forms, as the pythons, boas, and *Tortrices*, the pelvis exists in a rudimentary state, and attached to it is a pair of rudimentary hind legs ending in claws ; in all other existing reptiles the limbs are directly comparable with those of birds and mammals, the bones of the legs being best developed in the Chelonians (turtles), which have nine carpal bones and five fingers in each foot. Certain extinct saurians had paddle-like limbs, others bird-like limbs, and still others approached the crocodilian type, in which the carpal bones and phalanges become reduced in number. In the hind limbs an intermedium (in birds only present in the embryo) is united with the *tibiale* bone to form an *astragalus* or heel-bone.

The scales of reptiles are very characteristic, though scales existed on the underside of the body of most Stegocephalous Batrachia. The scales of lizards and snakes are developed from the cutis. The large horny plates of Chelonians are greatly developed and unite above with the "ribs" to form the shell or *carapace*, while nine large plates below form the *plastron*.

The teeth are simple, conical, and while in the lizards and snakes they may exist on the palatine and pterygoid bones, in the crocodiles, where they are implanted in sockets of the jaw-bones, they are, as in the mammals, confined to the maxillary bones. They are reproduced as fast as they are shed. The Chelonians have no teeth, the jaws being, as in birds, enclosed in a stout horny case, developed from the epidermis. There is a middle and internal ear much as in birds. The New Zealand lizard, *Hatteria*, is the only reptile which has the beginning of a spiral turn indicated in its cochlea, which in other reptiles is, as in birds, merely a flask-shaped cavity. (Rolleston.) The eyes of reptiles approach those of birds, and in both there is an upper and a lower movable eyelid besides a nictitating membrane.

True nostrils exist in reptiles for the first time among Vertebrates.

The tongue is either not extended out of the mouth, and is broad, as in turtles and crocodiles and some lizards, or as in most lizards and all snakes it is long, slender, forked, and can be darted rapidly out of the mouth.

True lips now, as in birds, border the jaw-bones, while salivary glands for the first time in the Vertebrates appear in the Chelonians and lizards; besides these there are smaller glands in the lips of lizards and snakes, the poison-glands of the rattlesnake, viper, etc., being modifications of these labial glands.

While the œsophagus is wide and the stomach usually quite simple, in the crocodiles there is a muscular gizzard approaching that of birds, and there is a special pyloric portion in the crocodiles like that of grallatorial and swimming birds. The liver and pancreas have, as in birds, two or more excretory ducts, and a gall-bladder is always present. A large fat-body (Fig. 440, *f*) is present on each side of the body.

The lungs, trachea, and larynx of reptiles are much simpler than in birds; in the long slender-ringed trachea there is an approach to that of birds, but the lungs are modelled on the Amphibian type; the larynx, especially in the Chelonians and crocodiles, is much more perfect than in the Amphibians.

The organs of circulation show a decided advance in situation over the Batrachians. The heart (Fig. 440) recedes farther back into the thorax. Of the two auricles the right and larger one receives the systemic and the left the pulmonary veins. In all but the crocodile the ventricle has a partition, the right half containing venous and the left arterial blood, while in the crocodiles there are two ventricles, so that the heart is four-chambered. In the lizards two aortic branches (a right and a left) survive. In the crocodiles a vessel which gives off the right aortic arch and the carotids arises from the left ventricle, while a left aortic arch and the pulmonary arteries arise from the right ventricle. In the reptiles as in birds there are two superior as well as one inferior vena cava. In reptiles as in lower Vertebrates there are no true lymphatic glands; an organ resembling them is present in reptiles (Fig. 440, *th*), forming a small swelling situated behind the angle of the lower jaw.

While the brain is still simple, though it fills the cavity of the skull, the different lobes being subequal in size, the cere-

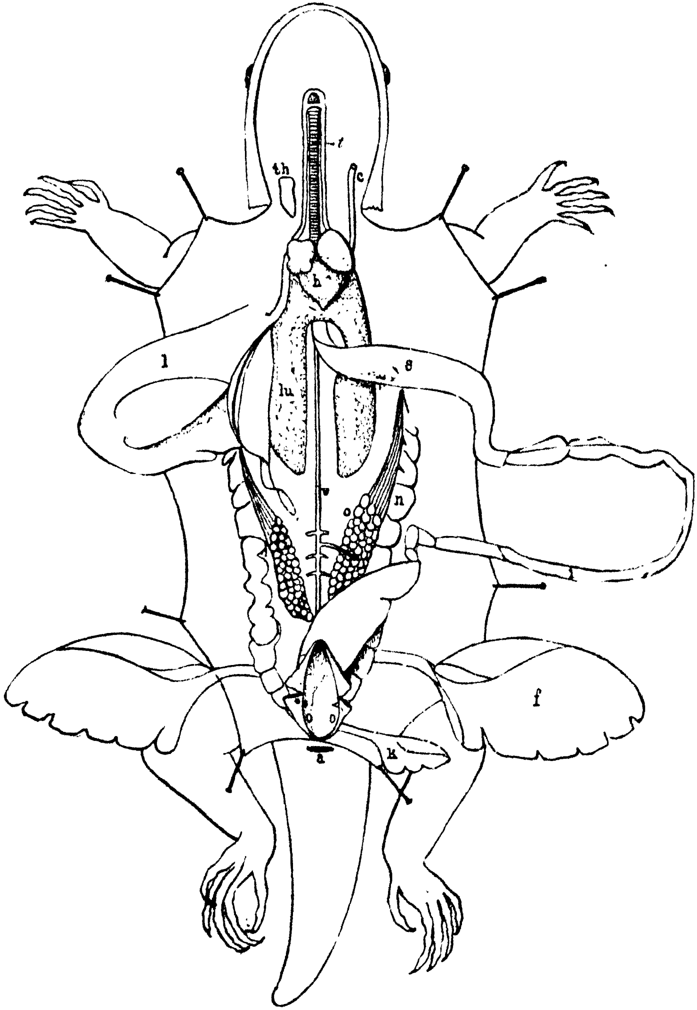

Fig. 440.—Anatomy of a lizard, *Sceleporus undulatus*. *t*, trachea; *c*, carotid artery; *th*, thyroid gland; *h*, ventricle of the heart—above are the two auricles; *lu*, lung; *l*, liver turned out; *s*, stomach; *i*, intestine; *a*, vent—above it the cloaca is laid open to disclose the openings (*o o*) of the kidneys (*k*); above are the two openings of the oviducts; *n*, oviduct; *o*, ovary; *v*, vena cava; *f*, fat-body.—Drawn by A. F. Gray from dissections made by the author.

bellum is small, especially in the serpents. In the crocodiles the brain most approaches that of birds, the cerebellum being larger than usual in the middle, and in this respect somewhat approaching the birds. Corpora striata (which are thickenings of the outer walls of the cerebral hemispheres) and the anterior commissure of the cerebral hemispheres are present for the first time in the vertebrate series.

The kidneys (Fig. 440, *k*) are lobulated, varying in form and position, and usually situated near the cloaca, the ureters being short and opening into the cloaca. The reproductive organs are generally like those of the Batrachians. The ovaries lie on each side of the vertebral column, and vary in size with the season, being largest during the time of reproduction. The oviducts (Fig. 440, *n*) are voluminous coiled canals, which in most reptiles open into the cloaca; in the turtles, however, opening into the neck of the so-called urinary bladder. After the egg passes into the oviduct it is enveloped by the "white" or albumen, which is secreted in the anterior part of the oviduct, while the thick-walled terminal part secretes the shell.

The external differences between the sexes is more marked than in the Amphibians. According to Darwin, the sexes of the Chelonians and snakes differ very slightly; male rattlesnakes are said to be more yellow; in the East Indian *Dipsas cynodon* the male is bright green, while the female is bronze-colored. Male lizards are usually larger, while male snakes are always smaller than those of the opposite sex. Various appendages, such as crests, warts, horns, etc., when present in both sexes, are most developed in the males, while the colors and markings are brighter in the latter sex.

The moulting of the skin is effected by its being pushed off by the upward growth of fine, temporary cuticular hairs. On certain parts of the body, as on the underside of the capsular skin and scales of the eyes, these hairs do not develop. After the skin is loosened, it dries and is readily shuffled off.

The eggs of turtles, like those of birds, are very large, the yolk mass being greatly developed. The lizards, snakes, and crocodiles lay their eggs in sand or light soil, while those of the iguana are laid in the hollows of trees. Certain snakes, as the vipers, are viviparous. In many snakes and lizards the development of the embryo goes on in the egg before it leaves the oviduct; such species are said to be *ovoviviparous*, the young being born living. The *Eutænia sirtalis*, or common striped snake, brings forth its young alive, and is probably ovoviviparous rather than viviparous.

The early phases of the development of the reptiles, including the origin of the amnion and allantois, is much as in the chick. In the turtle, by the time that the heart has become three-chambered, the vertebræ have reached the root of the tail, the eyes have become entirely enclosed in complete orbits, and the allantois begins to grow. The nostrils may now be recognized as two simple indentations at the end of the head, and at first are not in communication with the mouth, but soon a shallow furrow leads to it. The shield begins to develop by a budding out laterally of the musculo-cutaneous layer along the sides of the body, and by the growth of narrow ribs extending to the edge of the shield. In the oviparous snakes (*e.g.*, *Natrix torquata*) the embryo partially develops before the egg is laid, while the young hatches in two months after the egg is deposited. By this time the amnion is perfected, the head is distinct, and shows the eyeball and ear-sac; also the maxillary and mandibular processes. The allantois is about as large as the head. The long trunk of the serpent grows in a series of decreasing spirals, and when five or six are formed, the rudiments of the liver and the primordial kidneys are discernible. At the latter third of embryonic life the right lung appears as a mere appendage to the beginning of the left.

The reptiles are essentially tropical and subtropical animals; they are scarce in north temperate countries, though in North America snakes extend north farther than lizards; in Europe snakes cease at 60° north latitude, and at 6000 feet elevation in the Alps; lizards in Europe sometimes extend farther north than snakes, and ascend to an elevation of 10,000 feet in the Alps. Reptiles are usually wanting in oceanic islands which possess no indigenous mammals, though lizards are sometimes found on islands where there are neither mammals nor snakes. The reptiles in cool climates hibernate, while those of the tropics have a summer-sleep in the dry season, becoming active when the rainy season begins.

There are about three thousand species of living reptiles known, of which three hundred and fifty-eight are North American; between three and four hundred fossil forms have been described. The reptiles are divided into nine orders, of which five are extinct.

Order 1. *Ophidia*. The snakes, of which there are over one hundred and thirty species in America north of Mexico, have a remarkably long cylindrical body, the tail very long and slender; they are footless, with no shoulder girdle, and are covered with scales, which are all shed simultaneously. These scales are epidermal growths, and while usually they overlap, in a few cases (*Acrochordus, etc.*) they are tubercular, and do not overlap. The eyes are not protected by true lids, but the latter are thin, covering the eye permanently, thus accounting for the fixed, stony stare of snakes. The number of vertebræ (which are hollow in front and convex behind), may in the boa amount to more than four hundred. Each vertebra, except the first (the atlas) is provided with ribs, and the processes with articular facets, which interlocking give great strength and flexibility to the spinal column. The hyoid bone is very slightly developed, though the tongue is long, forked, can be rapidly darted out, and withdrawn into a sheath; the quadrate bones connecting the lower jaw with the skull are movable. The bones of the brain-case are firmly united together, while those of the jaws and palate are more or less freely movable to allow the snake (the boa especially) to distend its throat immensely and swallow comparatively large animals, though ordinary snakes will swallow large toads and frogs and other snakes but slightly smaller than themselves. In order to retain the prey and prevent its slipping out of the mouth, the recurved short conical teeth are developed on the maxillary, palatine, pterygoid, and mandibular bones, and occasionally on the premaxillaries; they are not set in sockets, and consequently are not used to crush or tear food.

The peculiar gliding motion of snakes is effected by the movements of the large ventral scales, which are successively advanced, the hinder edges of the scales resting on the ground and forming fulcra; resting on these the body is then drawn or pushed rapidly forwards.

The brain of serpents is small, much as in the lizards, the cerebellum being especially small and flat, while the cerebral hemispheres together form a mass broader than long.

The more characteristic features of the internal anatomy of snakes is a want of symmetry in the paired organs, as seen in the absence of a second functional lung, and second pulmonary artery, one of the lungs being minute, rudimentary, while the other is very long and large; the trachea is also very long, while the right ovary is larger than the left and placed in front of it. The other viscera are so arranged as to pack well in the long narrow body-cavity.

The student should dissect a snake with the aid of the accompanying figure of the common striped snake (*Eutænia sirtalis* Baird).

A few snakes are viviparous, as the vipers; others are ovoviviparous. In the oviparous *Natrix torquata* of Europe, the embryo partly develops before the egg is laid, while the young hatches in two months after the egg is deposited. At this time the amnion is fully formed, the head is distinct, as well as the eyeball, and ear sac. The long body grows in a series of decreasing spirals, and when five or six are formed, the rudiments of the liver and of the primordial kidneys may be detected, while at the latter third of embryonic life, the right lung appears as a mere appendage to the beginning of the left. The embryo, at the time of hatching, is provided with a temporary horny tooth on the snout to cut through the egg shell.

Most snakes conform in coloration to the nature of the soil or places they frequent; some being, as in the rattlesnake of the western plains, of the color of the soil in which they burrow; the little green snake is of the color of the grass through which it glides; other are dull gray or dusky, harmonizing with the color of the trunks of trees on which they rest. The poisonous *Elaps* of the Central American forest is gaily and conspicuously colored; indeed it can afford to be [illegible]

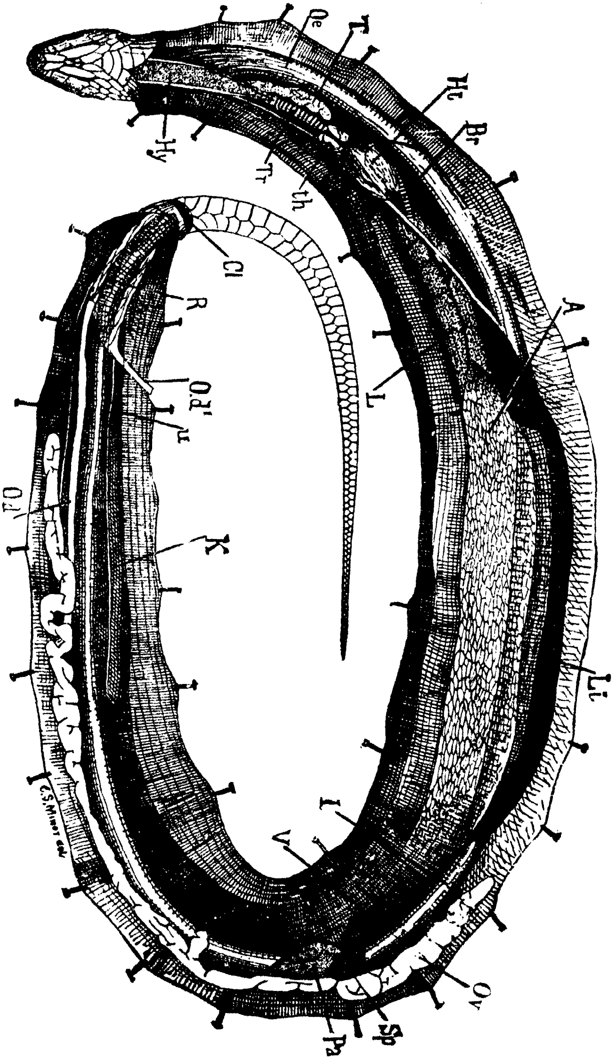

Fig. 441.—Anatomy of the common striped Snake. *Hy*, hyoidean apparatus; *Tr*, trachea; *th*, thyroid; *Oe*, œsophagus; *T*, thymus; *Ht*. heart; *Br*, bronchus; *L*, lung; *A*, air-sac; *Li*, liver; *Ov*, ovary; *Sp*, spleen; *Pa*. pancreas; *Od*, oviduct; *Cl*. cloaca; *R*, rectum; *Od'*, right oviduct cut off; *u*, ureter; *K*, kidney; *V*, vena portæ; *I*, intestine.—Drawn by C. S. Minot.

The Salenoglyph poisonous snakes may always be recognized by their broad, flattened heads, and usually short thick bodies. The poison gland of the rattlesnake (Fig. 442, *a*) is a modified salivary gland. The two fangs are modifications of maxillary teeth, each of which has been, so to speak, pressed flat, with the edges bent towards each other, and soldered together, so as to form a hollow cylinder open at both ends, the poison duct leading into the basal opening. When the fangs strike into the flesh, the muscles closing the jaws press upon the poison gland, forcing the poison into the wound. The poison-fangs are largest in the most deadly species, as the viper (*Vipera*), the puff adder (*Clotho*), the rattlesnake, and fer-de-lance (*Trigonocephalus*), but are small in the asps or hooded snakes (*Naja*). The bite of the rattlesnake is intensely painful; it is best cured by sucking, freely lancing, and by cauterizing the wound, and drinking large quantities (at least a pint) of whiskey or brandy, sufficient ordinarily to produce insensibility. Deaths from the bite of rattlesnakes are not common, while in India it is estimated that several thousand people annually die from the bite of the cobra—10,000 dying each year from the bite of snakes and the attacks of wild beasts. The "rattle" of the rattlesnake is a horny appendage formed of buttonlike compartments ; the sound made by the rattle, which has been compared by some to the stridulation of a Carolina locust, or of the Cicada, is an alarm note, warning the intruder ; the rattle is sprung before the snake strikes. Allied to this snake

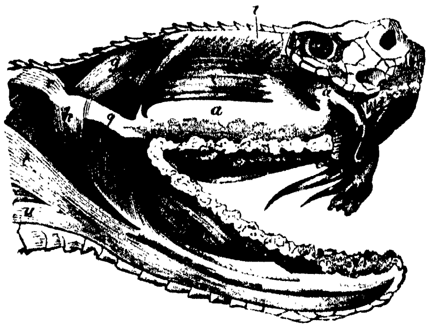

FIG. 442.—Head of the rattlesnake : *a a*, poison gland and its excretory duct : *e*, anterior temporal muscle ; *f*, posterior temporal muscle ; *g*, digastricus ; *h*, external pterygoid muscle ; *i*, middle temporal muscle ; *q*, articulo-maxillary ligament which joins the aponeurotic capsule of the poison gland ; *r*, the cervical angular muscle ; *t*, vertebro-mandibular muscle ; *u*, costo-mandibular muscle.—After Duvernoy.

is the copperhead (*Ancistrodon contortrix* Linn.) and the black mocassin (*Ancistrodon piscivorus* Linn.). In the water snakes the tails are laterally compressed, while the poison-fangs are small. These snakes are not much over a metre in length, and live far from land in the East Indian seas.

The poisonous snakes stand lowest in the series; they are succeeded by the striped snake, milk adder, and by the boas, which attain a length of five metres; while the anaconda grows eight metres long.

In time snakes reach back to the Eocene Tertiary period, when a great sea-snake (*Titanophis*), represented by several species, one six metres in length, haunted the coast of New Jersey, while in the western lake-deposits of the same age, forms allied to the existing boa-constrictor were not uncommon. The snakes, then, appear to be a modern type compared with the lizards, turtles, and crocodiles.

Order 2. *Pythonomorpha.*—This group includes a number of colossal serpent-like forms, with paddle-like feet, which are regarded by Cope as the types of a distinct order, characterized by a complex suspensorium, by the absence of a sternum and sacrum, by the rootless teeth, recurved parietal bones, etc.

They were fifty and sixty feet in length, and *Mosasaurus maximus* Cope, from New Jersey was still more colossal. They combined characters of the snakes, lizards, and plesiosaurs, and correspond in a degree to the descriptions of the mythical sea-serpent.

The resemblance to the Ophidians is still farther strengthened by the late discovery by Professor F. H. Snow, that one of the forms (*Liodon*) was covered above by small imbricated scales, like those of the snakes, rather than large ones, like those of reptiles. The more abundant type is the *Mosasaurus* of the Cretaceous seas, which was a huge sea-serpent originally referred by Cuvier and Owen to the neighborhood of the lace-lizards (*Varanidæ*); Cope describes it as a long slender reptile, with a pair of powerful paddles in front, a moderately long neck, and flat pointed head, with a long forked tongue. The very long tail was flat and deep, like that of a great eel, forming a powerful propeller. The arches of the vertebral column interlocked more extensively than in other reptiles except the snakes. They swam rapidly through the water by rapid undulations of their bodies aided by the paddles. The skull was not so strong, though as light as that of the serpents. "While the jaws were longer, the gape was not so extensive as in serpents of the higher groups, for the os quadratum, the suspensor of the lower jaw, though equally movable and fastened to widely spread supports, was much shorter than in them. But there was a remarkable arrangement to obviate any inconvenience arising from these points. While the branches of the under jaw had no natural connection, and possessed independent motion, as in all serpents, they had the additional peculiarity, not known elsewhere among Vertebrates (except with snakes), of a movable articulation a little behind the middle of each. Its direction being oblique, the flexure was outwards and a little downwards, greatly expanding the width of the space between them, and allowing their tips to close a little. A loose flexible pouch-like throat could then receive the entire prey swallowed between the branches of the jaw; the necessity of holding it long in the teeth, or of passing it between the short quadrate bones could not exist. Of course the glottis and tongue would be forwards." The order became extinct before the Tertiary Period.

Order 3. *Lacertilia.*—The existing lizards or *Saurians* are the survivors or descendants of a multitude of forms, many colossal in size, which characterized the Permian and Mesozoic periods; while the extinct forms of reptiles were in many cases synthetic types, with affinities to fishes, Amphibians, and even birds. The group as now existing is well circumscribed.

Most lizards have cylindrical bodies, usually covered with small overlapping scales, with a long, slender tail, and generally two pairs of feet, the toes long and slender, and ending in claws. They run with great rapidity, and are active, agile creatures, adorned with bright metallic colors, in some cases green or brown, simulating the tints of the vegetation or soil on which they live; some are capable of changing their color at will, as in the chameleon and Anolis; this is due to the fact that the pigment cells or chromatophores are under the influence of the voluntary nerves.

While the scales of the body are developed, as a rule, from the epidermis, in the scink there are dermal scales (scutes), and such dermal plates in the head may unite with the bones of the skull. In most lizards, all except the Geckos, the vertebræ are procœlous, *i.e.*, with a ball-and-socket joint, the vertebræ being rounded in front, and concave behind. In the Geckos the vertebral column is fish-like, the notochord persisting except in the centre of each vertebra, which is biconcave. In many lizards (*Lacerta*, *Iguana* and the Geckos), the middle of each caudal vertebra has a thin cartilaginous partition, and it is at this point that the tails of these lizards break off so easily when seized. In such cases the tail is renewed, but is more stumpy. The tail of the specimen of Sceloporus (Fig. 440) which we dissected is much shorter than in the normal animal, and must have grown out after having been lost.

The throat is often distensible by the hyoid apparatus; but the bones of the jaws are firm, the bones united in front. Both jaws are provided with teeth, while some have them developed on the palatine and pterygoid bones. The teeth are usually simple, sharp, conical, as in most lizards, including the Monitor, or they are flattened, blade-like, with serrated edges, as in the *Iguana*, or as in *Cyclodus* they are broad, adapted for crushing the food. Most lizards prey on insects; some live on plants. New teeth are usually developed at the bases of the old ones. They are attached to the surface of its jaws; in certain extinct forms (*Thecodonts*) they are lodged in sockets. (Huxley.) The eyelids are well developed except in the Geckos, in which the lids are modified somewhat, as in the snakes, to form a transparent skin over the cornea of the eyes. The tongue is free and long, sometimes forked; in the iguana it ends in a horny point.

While the limbs are usually present, one or the other pair may in rare cases (in *Pseudopus* the fore feet are wanting; in *Chirotes* the hind feet are absent) be absent, or as in *Amphisbæna* and its allies the feet are entirely wanting, though the shoulder-girdle invariably remains, the pelvic-girdle in such cases disappearing; the pelvis being complete, however, when the hind limbs are present. The feet are five-toed. The internal anatomy of lizards has already been described and illustrated on p. 493. In the snake-like lizards (*Anguis*) the left lung is the smaller, and in *Acontias* and *Typhline* it is almost wanting. A urinary bladder, wanting in the snakes, is present in lizards.

The lizard lays eggs in the sand or soil; those of the iguana are deposited in the hollows of trees. Certain lizards are viviparous.

There are between seven hundred and eight hundred species of existing lizards, most of which inhabit tropical or subtropical countries; eighty-two species of lizards inhabit America north of Mexico. The earliest lizards date back to the Kimmeridge or middle division of the Jurassic rocks.

Reviewing some of the more interesting lizards in the ascending order, we may, passing over the snake-like, limbless *Amphisbœna*, and the limbless glass snake (*Opheosaurus*), first consider the chameleon of the Mediterranean shores, in which the eyes are movable with a circular eyelid, and with the five toes in two opposable groups adapted for grasping twigs of trees. It is remarkable for its power of changing its colors. The tongue of the chameleon (Fig. 443) is capable of extending five or six inches, and is covered with a sticky secretion for the capture of insects, as the creature itself is very sluggish. The chameleon of our country is the *Anolis* of the Southern States, and is a long smooth-bodied lizard, which can change its color from a bright pea-green to a deep bronze-brown.

The horned toads (*Phrynosoma*) are characteristic of the dry western plains; the body is broad, flattened, and armed with spines; its coloration depends on that of the soil it inhabits. It will stand long fasts. When *Phrynosoma Douglassii* of the Northwestern Territories and States is about to moult, small dry vesicles appear on the back and sides, running along the horizontal rows of pyramidal scales forming the margin of the abdomen. In a day or two the vesicles break and desquamation begins, which continues for eight or ten days, the skin finally separating from the spines of the head and the claws. (Hoffman.)

Our most common lizard in the Middle and Southern States is *Sceloporus undulatus* Harlan (Fig. 440). It is common, running up trees. The iguanas are very large lizards inhabiting the West Indies and Central America; the head is protected by numerous small shields, with a dorsal row of bristling spines. They are about three feet long, live in the lower branches of trees, and are said to be excellent eating. A still larger form, closely resembling the iguanas, is the sea-lizard (*Amblyrhynchus*) of the Galapagos Islands, where it lives in the rocks by the shore, feeding on seaweeds. These large creatures are among the largest of existing lizards, being eighty-five centimetres (over 3 feet) in length. Closely allied to the iguanas were a number of extinct saurians of colossal size which flourished in the Jura-Trias and Chalk Periods.

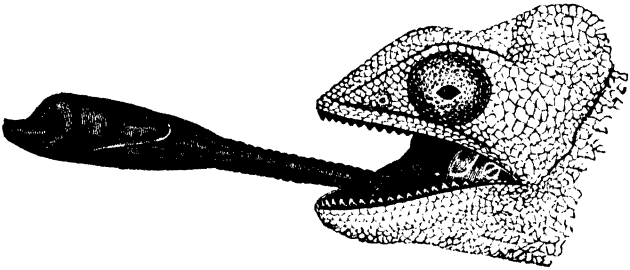

Fig. 443.—Tongue of *Chameleon*. Natural size.—After Rymer Jones.

The largest lizard in Mexico is the *Heloderma horridum* of Wiegmann. It grows to the length of one metre (over three feet). It is allied to the iguanas, but the body is heavily tuberculated. *Heloderma suspectum* Cope, inhabits southern Utah, Arizona, and New Mexico. The largest of the existing lizards are the monitors, or species of *Varanus,* of tropical rivers, which nearly rival the crocodiles in size, being five or six feet in length.

Order 4. *Chelonia.*—Although the tortoises and turtles are a well circumscribed group, with no aberrant or connecting forms, yet they have some affinities with the *Batrachia.* They are distinguished from the other reptiles by the shell, the upper part forming the *carapace,* and the lower the *plastron;* these two parts unite to form a case or box within

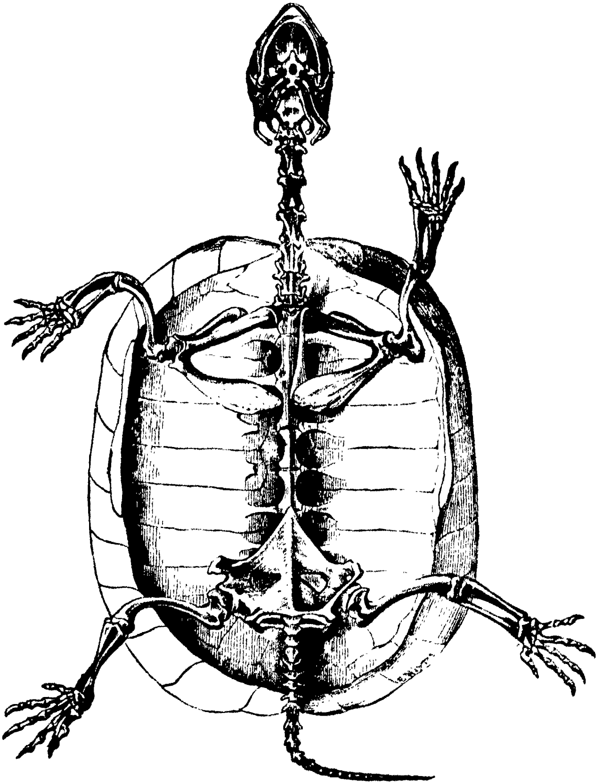

Fig. 444.—Skeleton of European Tortoise, with the plastron or under shell removed. —After Owen.

which the turtle can retract its head and limbs and tail. Owing to the presence of the carapace, the dorsal vertebræ are immovable, and the ribs do not move upon the vertebræ.

The bones of the ventral shield or plastron are usually nine in number. The jaws are toothless, being, as in birds, encased in horny beaks; there are rarely fleshy lips; the tongue is spoon-shaped and immovable. The heart consists of two auricles and a ventricle. The brain has larger cerebral lobes than in the lizards. The eyes have a third lid, or nictitating membrane. The student can best obtain an idea of the organization of the turtles by studying the skeleton and dissecting a turtle with the aid of the accompanying description and figure of the common turtle.*

The common swamp-turtle (*Chrysemys picta*) is a good type of the *Chelonia*. The animal is enclosed in a hard shell made up of an arched dorsal portion, and a flat ventral portion, the two connected laterally, but widely separated anteriorly to give exit to the head and fore limbs, and posteriorly for the tail and hind limbs. These parts can all be withdrawn within the protecting shell, by being doubled or folded back upon themselves. The soft parts of the skin are covered with scales, formed by overlapping folds. The limbs are stout; upon the anterior feet there are five, upon the posterior four claws. On the under surface of the short tapering tail near its base is the wide opening of the cloaca. The ventral plastron consists of twelve symmetrical pieces, six on each side, Fig. 445. The first and last pair are triangular, the others are four-sided; the fourth pair is the

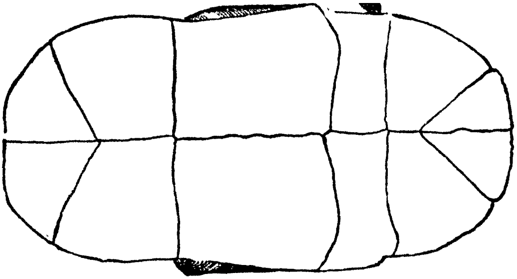

Fig. 445.—Ventral epidermal plates of *Chrysemys picta*.—Drawn by C. S. Minot.

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* This description has been prepared and the illustrations drawn by Dr. C. S. Minot.

largest. Underneath the epidermal plates are nine bony pieces. The dorsal *carapace* is composed of thirty-eight plates, twenty-five marginal, of which the most anterior lies in the middle line ; there are five median plates and a lateral row of four plates on each side.

To dissect a turtle, saw through the lateral pieces of the shell which unite the plastron and carapace, then remove the ventral piece, carefully freeing it from the organs beneath.

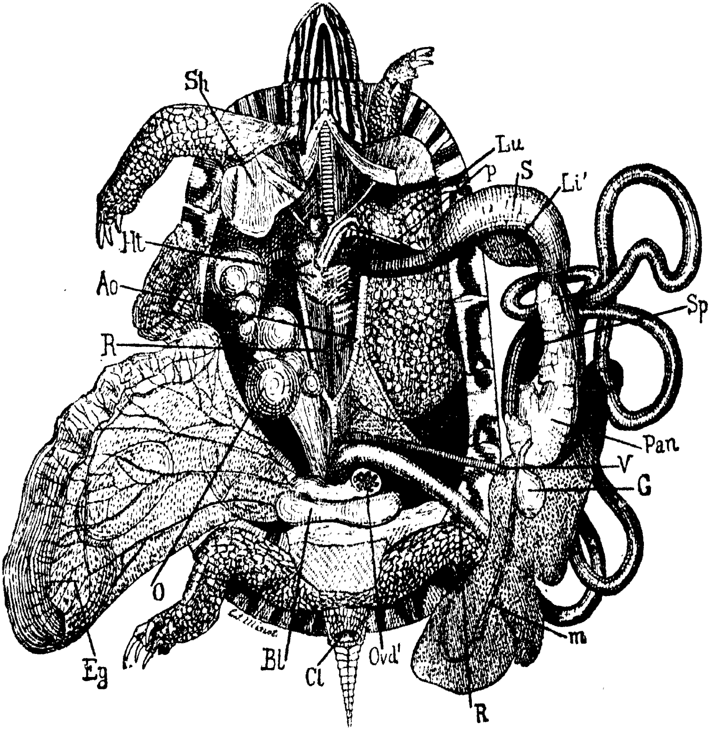

Fig. 446.—Anatomy of the Turtle, *Chrysemys picta.*—Drawn by C. S. Minot.

Fig. 446 represents a female, with the intestines and digestive glands partially freed and turned aside, while the shoulder-blade, oviduct, and ovary of the left side and the right lung have been entirely removed. The middle line of the neck is occupied by the trachea, which overlies the much wider œsophagus, which again rests upon two very large cylindrical muscles, the powerful retractors of the head. The muscles (*R*) extend backwards along the vertebral column, behind the heart and through the abdomen. The trachea branches just in front of the heart, to send a bronchus to each lung. The left bronchus can be seen in the figure, passing between the pulmonary artery (*p*) in front, and the pulmonary vein behind; the three tubes run closely parallel forming the so-called root of the lung. Each lung (*Lu*) is a large elastic sack with numerous air-cells. The size of the lung depends upon its degree of expansion; when entirely collapsed it is quite small, but it may easily be blown up through the trachea. The heart (*Ht*) is much broader than in the frog or bird. We shall recur to its structure presently.

Below the trachea lies the much larger œsophagus, a cylindrical tube with muscular walls. The œsophagus terminates in the stomach (*S*), which, together with the remaining digestive organs and the spleen, is drawn aside in the figure. The long and coiled intestine can be followed to the point where it passes under the oviducts (*ovd*) and the bladder (*Bl*) to terminate in the cloaca, the external opening of which is represented at *Cl*. The main mass of the elongated, gray, and mottled liver lies upon the intestine, being turned so as to show its raphe (*m*), by which it is suspended from the peritonæum, the portal vein (*v*), and the retort-like gall-bladder (*G*); the gall duct passes through the body of the pancreas (*Pan*), an elongated whitish mass resting upon the first coil of the intestine, the so-called duodenum. Alongside the pancreas is the much smaller dark oval spleen (*Sp*).

The specimen figured is a female killed during the period of reproduction. The genital organs are therefore enormously developed. The long and prominent oviducts contained eggs already provided with a shell. The right oviduct is seen drawn out and suspended by a mesentery, a thin and transparent membrane with numerous blood vessels. The lower end of the oviduct is seen through the mesentery, and contains three oval eggs, one of which is lettered *Eg*. The oviduct can be followed to its anterior end which is much pigmented and has a terminal opening. The cut-end of the left oviduct (*ovd*) shows the folds of the lining mucous membrane.

The ovary (*o*) is likewise suspended by a thin membrane, the mesovarium, and is equally developed on both sides in a complete specimen. It is easily recognized by the numerous bulging yellow spheres, of all sizes, which are the egg-yolks in various stages of development.

The heart of the turtle (Fig. 447) will repay careful dissection. A small round body lies just in front of it; this is usually considered the equivalent of the thyroid gland, through its real nature is still uncertain. The heart itself (Fig. 447) consists of two auricles and one ventricle (*ven*), with an imperfect internal septum. It receives the veins upon its dorsal surface, and gives off the arterial trunks from its ventral side. The two auricles are equal in size; together they a little more than equal the ventricle. The arterial vessels arise together a little to the right, and are most conveniently described as three in number: 1st. The right aorta (*R Ao*) arising on the left; 2d. The left aorta on the right (*L Ao*); the two cross near their origin and curve upwards and backwards, to reunite posteriorly just in front of the retractor muscles, their union forming the single median descending aorta; 3d. The pulmonary aorta (*pa*), which soon divides into a branch for each lung. The left aorta gives off a branch (*d*) which persists as a mere cord, the remnant of the *ductus arteriosus*, which originally united the aorta with the pulmonary artery. The right aorta gives off an *innominate* branch, that soon divides, and from each division springs

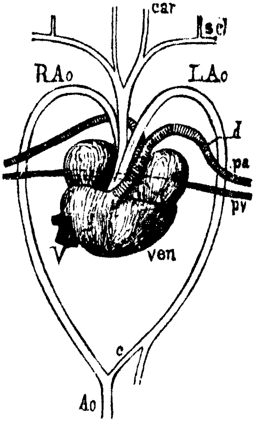

Fig 447.—Ventral surface of the heart of the Turtle, *Chrysemys picta*. Dissected and drawn by C. S. Minot.

the *carotis* (*car*), and subclavian artery of the same side. The veins are two in number, as they enter the heart: 1st. The pulmonary veins (*pv*) unite to form a very short trunk emptying into the left auricle; while (2d) the two *venæ cavæ superiores* unite with the *cava inferior* (*V*) to empty through the *sinus venosus* into the right auricle.

The kidneys lie at the posterior end of the body against the vertebral column. In the figure they are concealed by the bladder and oviducts. (Minot.)

There are about forty species of Chelonians in America north of Mexico. The lower forms of turtles are the marine species. Such is the great sea-turtle (*Sphargis coriacea* Gray) of the Atlantic and Mediterranean, which is the largest of all existing turtles, and is sometimes eight feet long, weighing from eight hundred to twelve hundred pounds. Next to this species is the loggerhead turtle (*Thalassochelys caouana* Fitzinger), which is sometimes seen asleep in mid-ocean. Still another is the hawk-bill or tortoise-shell turtle (*Eretmochelys imbricata* Fitz.), the plates of whose shell is an article of commerce. The green-turtle of the West Indies weighs from two hundred to three hundred pounds, and is used for making delicious soups and steaks; being caught at night when laying its eggs on sandy shores. All the foregoing species have large, flat, broad flippers or fin-like limbs, while in the pond and river turtles the feet are webbed, and the toes distinct. A very ferocious species is the common soft-shelled turtle (*Aspidonectes spinifer* Lesueur), whose shell is covered with a thick leathery skin. It is carnivorous, voracious, living in shallow muddy water, throwing itself forward upon small animals forming its prey. The snapping-turtle (*Chelydra serpentina* Schweigger) sometimes becomes five feet long; its ferocity is well known; the flesh makes an excellent soup.

The terrapins belong to the genus *Pseudemys;* the pretty painted turtle (*Chrysemys picta* Agassiz) is common in the Eastern States, while the *Nanemys guttatus* (Agassiz), or spotted tortoise, is black, spotted with orange. In the land tortoises the feet are short and stumpy. The *Testudo Indica* of India is three feet in length. The great land tortoises of the Galapagos Islands, the Mascarine Islands (Mauritius and Rodriguez), and also of the Aldabra Islands, lying northwest of Madagascar, are in some cases colossal in size, the shells being nearly two metres (six feet) in length. The fierce Mascarine species were contemporaries of the dodo and solitaire, and are now extinct. The bones of extinct similar species have been found in Malta and in one of the West Indian islands. The land tortoises are long-lived and often reach a great age. Certain tortoises of the Tertiary Period, as the *Colossochelys* of the Himalayas had a shell twelve feet long and six feet high. The turtles extend back in geological time to the Jurassic, a species of *Compsemys* being characteristic of the Upper Jurassic beds of the Rocky Mountains. (Marsh.)

The eggs of turtles, as those of birds, are of large size; they are buried in June in the sand and left to be hatched by the warmth of the sun. It is probable that turtles do not lay eggs until eleven to thirteen years of age. The development of turtles is much as in the chick. By the time the heart becomes three-chambered, the vertebræ develop as far as the root of the tail, and the eyes are completely enclosed in their orbits. The shield begins to develop as lateral folds along the sides of the body, the narrow ribs extending to the edge of the shield. In the lower forms of turtles (the *Chelonioidæ*), the paddle-like feet are formed by the bones of the toe becoming very long, while the web is hardened by the development of densely packed scales, so that the foot is nearly as rigid as the blade of an oar.

Order 5. *Rhynchocephalia.*—The only living representative of this order is the *Sphenodon* or *Hatteria* of New Zealand; a lizard-like form of simpler structure, however, than the lizards in general. This rare creature somewhat resembles an iguana in appearance, having a dorsal row of spines. It is nearly a metre (32 inches) in length. In this group the vertebræ are biconcave; the quadrate bone is immovable, and there are other important characters based on a study of the living and fossil forms, the latter represented by the Triassic *Rhynchosaurus* and *Hyperodapedon.*

Order 6. *Ichthyopterygia.*—This order is entirely extinct.

The Ichthyosaurs were colossal reptiles from two to thirteen metres (six to forty feet) in length, swimming in the ocean by four paddle-like limbs consisting of six rows of digital bones; the head was very large, the neck very short, and the orbits were enormous; the vertebræ were remarkably short and biconcave. They were carnivorous, and powerful swimmers, and common in the Jurassic seas of Europe; one form existed in the Jurassic times in Wyoming.

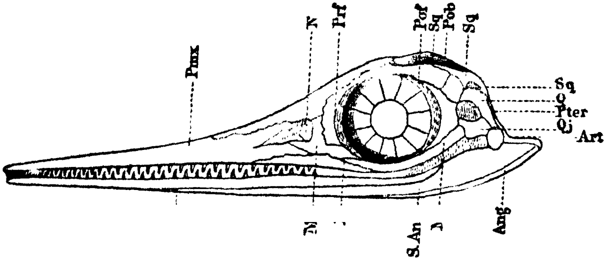

Fig. 448.—Skull of *Ichthyosaurus*; lateral view. *Pmx*, premaxillary bone; *Mx*, maxillary; *N*, nasal; *Fr*, frontal; *Prf*, prefrontal; *Pof*, postfrontal; *Pa*, parietal; *L*, lachrymal; *M*, malar; *Qj*, quadratojugal; *Q*, quadrate; *Pob*, postorbital; *Sq*, squamosal; *D*, dentary; *Ang*, angular; *Art*, articular; *S. Ar*, subarticular; *Pter*, pterygoid.—After Cope.

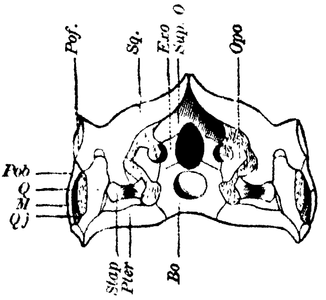

Fig. 449.—Posterior view of the skull of *Ichthyosaurus*; lettering as in Fig. 443, with following additions; *Bo*, basioccipital; *Exo*, Exoccipital; *Sup. O*, supraoccipital; *Opo*, opisthotic; *Stap*, suprastapedial or hyomandibular.—After Cope.

Order 7. Theromorpha.—This order is divided into the *Pelycosauria* and *Anomodontia*. The beaked Saurians were somewhat lizard-like, but were synthetic types, combining the characters of the Ichthyosaurs, the turtles, the *Sphenodon*, with those of lizards, Dinosaurians, and crocodiles. The skull was short, and in *Dicynodon* the jaws in front had the nipping, horny beak of a turtle, while from behind in the upper jaw protruded two long, curved, canine teeth. *Dicynodon tigriceps* Owen, had a skull about half a metre (20 inches) long,

Another form was still more like the turtles, the jaws being toothless and enclosed in a nipping, horny beak. In *Lystrosaurus* (Fig. 450) the head was blunt, the jaws armed in front with stout teeth, and behind with canine teeth; and these animals, anticipating in their dentition the lions and tigers, were called by Owen *Theriodonts* (beast-toothed). These forms lived during the Permian and Triassic times.

Order 8. *Sauropterygia.*—The *Plesiosaurus* is the type

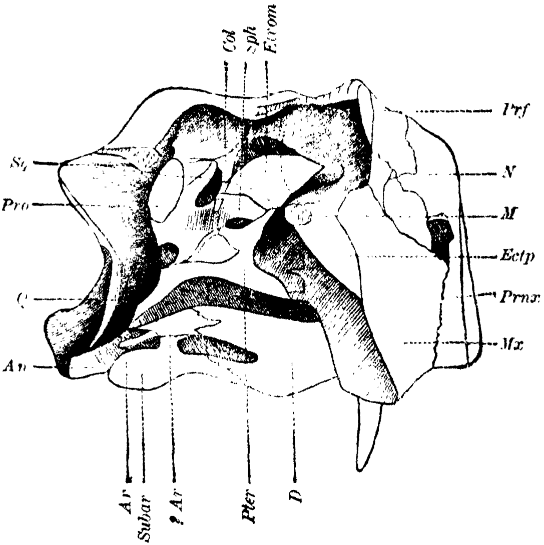

Fig. 450.—Skull of *Lystrosaurus frontosus* from Cape Colony. Profile. Lettering as in Fig. 443 and 444, with the following additions: *Etvom*, ethmovomerine; *Sph*, sphenoid; *pro*. Prootic; *Pter*, Pterygoid; *Col*, Columella; *Ectp*, Ectopterygoid; *Subart*, subarticular bone.—From Cope.

of this extinct order. The Plesiosaurs were somewhat like the Ichthyosaurs, swimming by paddle-like feet, but the neck was very long, and the head rather small. The largest true Plesiosaur was about nine metres in length. They abounded during the Jurassic and Cretaceous period. During the latter period off the coast of New Jersey and in the seas of Kansas flourished huge Plesiosaurian reptiles, such as *Elasmosaurus*, which had an enormous compressed tail. The vertebræ of *E. platyurus* Cope, of the New Jersey marl-beds, had vertebræ nearly as large as those of an elephant, while the creature was whale-like in bulk, the neck long and flexible, the paddles short. The skull was light, with a long, narrow, very flat muzzle It must have been the terror of those times; it was about fifteen metres (45 feet) in length. (Cope.)

Order 9. *Crocodilia.*—The crocodile, caiman, gavial, and alligator are the types of this well-known group. They present a decided step in advance of other reptiles, the heart approaching that of birds, in having the ventricle completely divided by a septum into two chambers; the venous and arterial blood mingle outside of the heart, not in it, as in the foregoing living orders. The brain is also more like that of birds, the cerebellum being broader than in the other reptiles. The nostrils are capable of closing, so that crocodiles and alligators draw their prey under the water and hold them there until they are drowned; but they are obliged to drag them ashore in order to eat them. The skin is covered with bony, epidermal scales. The conical teeth are lodged in sockets in the jaws. The vertebræ are concave in front and convex behind, or the reverse; the quadrate bone is immovable. The feet are partly webbed. The crocodiles and gavials appeared during the Jurassic period, but the early forms were marine and like gavials, the head being long and narrow in front, with biconcave vertebræ. They lay from twenty to thirty cylindrical eggs in the sand on river banks. The crocodiles are distributed throughout the tropics, even Australia; the gavials are mostly confined to India and Malaysia, and also Australia. The group is represented in the Southern States by the alligator (*A. Mississippiensis* Daudin). It is nearly four metres (10–12 feet) long; while the Florida crocodile (*C. acutus* Cuvier,

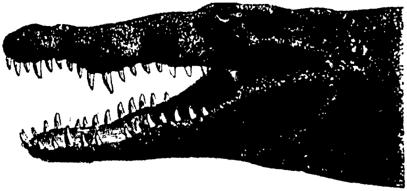

FIG. 451.—Head of the Florida Crocodile.—After Hornaday.

Fig. 451) in which the jaws are much narrower, is over four and a half metres (14 feet) long. It inhabits the rivers of Florida where it is very rare, and also the West Indies and South America. The cayman of Guiana belongs to a distinct genus, *Caiman*, and is characteristic of the rivers of tropical South America.

Order 10. *Dinosauria.*—We now come to reptiles which have more decided affinities as regards their skeleton (the only parts preserved to us) to the birds, especially the ostriches, than any reptiles yet mentioned; while the Dinosaurs were genuine reptiles, in the pelvis and hind limbs, including the feet, they approached the birds. This is seen especially in the ischium, which is long, slender, and inclined backwards as in birds. In the hind limbs the resemblance to birds is seen; among other points, in the ascending process of the astragalus, in the position of the farther (distal) end of the fibula, and in their having only three functional toes. The fore limbs were shorter and smaller than the hind extremities, sometimes remarkably so. Moreover, the limb-bones, vertebræ, and their processes were sometimes hollow; the sacrum consisted of four or five consolidated vertebræ, in this respect anticipating the birds and mammals. They walked with a free step, like quadrupeds, instead of crawling like reptiles; some walked on the hind legs alone, making a three-toed footprint, occasionally putting down the forefoot, like the kangaroo. The largest Dinosaurs were the *Iguanodon*, which was from ten to sixteen metres (30–50 feet) in length, and the *Camarasaurus* (Atlantosaurus) which was about twenty-seven metres (80 feet) in length. The *Cetiosaurus* had a length of from twenty to twenty-three metres (60–70 feet). The *Hadrosaurus* stood on its ponderous hind legs, with a stature of over eight metres (25 feet). These were bulky, inoffensive, herbivorous monsters, able to rise up on their hind feet and browse on the tops of trees; their undue increase was prevented by carnivorous forms like *Lælaps*, which was an active, possibly warm-blooded Dinosaur, with light, hollow bones, large claws, and serrate, conical teeth. It stood six metres (18 feet) high, and could leap a distance of ten metres through the air. (Cope.)

Still nearer the birds was the *Compsognathus;* it was only two thirds of a meter (2 feet) long, with a light head, toothed jaws, and a very long, slender neck ; the hind limbs were very large and disposed as in birds, the femur being shorter than the tibia ; moreover, the fore legs were very small. "It is impossible," says Huxley, "to look at the conformation of this strange reptile and to doubt that it hopped or walked, in an erect or semi-erect position, after the manner of a bird, to which its long neck, slight head, and small anterior limbs must have given it an extraordinary resemblance." The so-called bird tracks of the Triassic rocks of the valley of the Connecticut were all reptilian footprints, and without doubt made by Dinosaurs with the above-mentioned affinities to the birds. These bird-like, colossal lizards appeared in the Jura-Trias Period, and became extinct in late Cretaceous times.

Order 11. *Pterosauria.*—The forms of this order, represented by the Pterodactyles, would lead one to infer that the group was still more bird-like than the Dinosaurs, and Seeley has shown that they have as many and important points of similarity to that class as the preceding group. They are a sort of reptilian bats, forming links between reptiles and flying birds, as the Dinosaurs connect with the ostriches, and it is in the hand and foot, which in birds are the most characteristically ornithic, that they resemble the ornithic type. They also approach birds in their long heads and necks, the jaws with or without teeth, the short tail, in the skull which is more rounded and bird-like than in other reptiles, with large orbits, as also in the form of the brain ; while the jaws were probably, in part at least, encased in horny beaks. The shoulder girdle was bird-like, and the sternum was keeled, but the pelvis and limbs were like those of lizards, while the fore-feet were much larger than the hinder ones, and the ulnar finger was enormously long and probably supported a broad membrane, connecting the fore and hind limbs, as in bats; moreover, the limb bones were hollow, and air-cells were present, so that these winged lizards could fly like birds or bats. The jaws of the Pterosaurs were completely toothed ; those of the

Rhamphorhynchus had teeth in the back of the jaw, the ends of the jaws being toothless and probably encased in horny beaks, while in *Pteranodon* the jaws were toothless. They were of different size, some expanding only as much as a sparrow, others with a spread of about nine metres (27 feet). They were contemporaries of the Dinosaurs, several forms, discovered by Marsh, occurring in the Cretaceous beds of Kansas.

CLASS V. REPTILIA.

Air-breathing Vertebrates, with limbs usually ending in claws; limbs sometimes absent, rarely paddle-shaped; body scaled; ribs well developed; heart in the highest forms four-chambered; cold blooded; an incomplete double circulation; oviparous; eggs large; embryo with an amnion and allantois; no metamorphosis.

Order 1. *Ophidia.*—Body long, cylindrical, usually limbless; no shoulder girdle. (Eutænia.)

Order 2. *Pythonomorpha.*—Extinct, snake-like, limbs paddle-shaped. (Mosasaurus.)

Order 3. *Lacertilia.*—Body with a long tail; usually four limbs; mouth not dilatable, the bones of the jaw being firm. (Sceleporus.)

Order 4. *Chelonia.*—Body enclosed in a thick shell, within which the head and limbs can be withdrawn. (Testudo.)

Order 5. *Rhynchocephalia.*—Lizard-like; vertebræ bi-concave, species mostly extinct. (Sphenodon.)

Order 6. *Ichthyopterygia.*—Head large, orbits large; limbs paddle-shaped; extinct forms. (Ichthyosaurus.)

Order 7. *Theromorpha.*—Mammal-like saurians with solid pelvis and shoulder-girdle, and with canines, or toothless and beaked. (Dicynodon.)

Order 8. *Sauropterygia.*—Extinct colossal saurians, with long necks, head of moderate size. (Elasmosaurus.)

Order 9. *Crocodilia.*—Thick-scaled; heart four-chambered. (Crocodilus.)

Order 10. *Dinosauria.*—Colossal extinct saurians, capable of rising and resting on the hind legs, and making three-toed tracks. (Hadrosaurus.)

Order 11. *Pterosauria.*—Extinct flying saurians, with the fore limbs large and a very long ulnar finger; toothed or toothless. (Pterodactylus.)

CLASS VI. AVES (*Birds*).

General Characters of Birds.—We have met in the reptiles, especially in the fossil forms, many characters indicating that birds are by no means so specialized or so well circumscribed a group as was formerly supposed. Such a relationship between the two classes has recently been still further exhibited by Meyer's discovery of *Archæopteryx lithographica* of the Solenhofen slates of the Jurassic beds of Germany, and by Marsh's discovery of birds with teeth and biconcave vertebræ in the Cretaceous rocks of North America. On account, therefore, of the close relations between birds and reptiles, Huxley has placed these two classes in a series called *Sauropsida*, which may be opposed to the *Ichthyopsida* (Fishes and Batrachians) on the one hand, and the *Mammalia* on the other, by the following characters :—

Sauropsida.—There are no mammary glands. There is an amnion and an allantois; the species are oviparous or ovoviviparous, with reproductive organs and digestive canal opening into a common cloaca, and Wolffian bodies replaced functionally by permanent kidneys. There is no corpus callosum, nor complete diaphragm. Respiration is effected by lungs, never by gills. The heart is two or three chambered, and there are usually two or three aortic arches; in birds but one; there are red oval nucleated blood corpuscles. The bodies of the vertebræ are ossified, but without terminal epiphyses. There is a single convex, occipital condyle, in connection with an ossified basi-occipital. The ramus of the mandible consists of several pieces, the articular one of which is connected with the skull by a quadrate bone. The ankle-joint is between the proximal and distal divisions of the tarsus. The skin usually developes scales or feathers.

These important characters, derived from Huxley (as are many of those given beyond for the class *Aves*), may remind the student of the actual affinities between birds and reptiles. The former are distinguished from other *Sauropsida* by the following peculiarities :—

Aves.—The body is covered with feathers, a kind of dermal outgrowth found in no other animals. The fore limbs form wings, serviceable in nearly all cases for flight. There are never more than three digits in the hand, two of them usually much reduced, and none of them bearing claws (with rare exceptions); nor more than two separate carpal bones in adult recent birds; nor any separate interclavicle; the clavicles are normally complete, and coalesce to form a "merry-thought." The sternum is large, and usually keeled (the only exception among recent forms being the struthious birds); it ossifies from two to five or more centres, and the ribs are attached to its sides. The skull articulates with the spinal column by a single median convex condyle, developed in connection with a large ossified basi-occipital. The lower jaw consists of several pieces, articulated by a quadrate bone to the skull, and in all recent birds both jaws are toothless and encased in a horny beak. The bodies of at least some of the vertebræ of recent birds have sub-cylindrical, articular faces; when these faces are spheroidal, they are opisthocœlian, but some fossil forms are amphicœlian. The proper sacral vertebræ have no expanded ribs abutting against the ilia. The ilia are greatly prolonged forwards; the acetabulum is a ring, not a cup; the ischia and pubes are prolonged backwards; there is no ischial symphysis; there may be a prepubis; a process of the astragalus early anchyloses with the tibia. The incomplete fibula does not reach the ankle-joint; there are not more than four digits, the normal numbers of phalanges of which are 2, 3, 4, 5. The 1st metatarsal is incomplete above; the 2d, 3d and 4th anchylose together, and with the distal tarsal bone unite to form a tarso-metatarsus. The heart is completely four-chambered; there is but one aortic arch (the right), and but one pulmonic trunk from the right ventricle; the blood is red and hot. The large lungs are not free in the cavity of the thorax, but fixed and moulded to the walls of that cavity; and in all recent birds the larger air-passages of the lungs terminate in air-sacs. More or fewer of the bones are usually hollow, and permeable to air from the lungs. There is at most a rudimentary diaphragm. The eggs are very large, in consequence of a copious supply of albuminous substance, in the form of yolk and white, and are enclosed in a hard

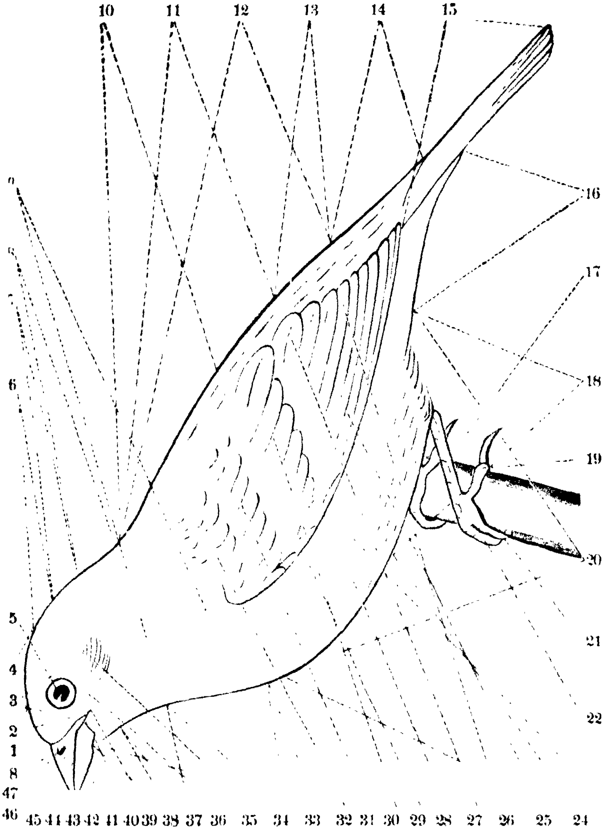

Fig. 452.—Topography of a bird. 1, forehead (*frons*); 2, lore; 3, circumocular region; 4, crown (*vertex*); 5, eye; 6, hind head (*occiput*); 7, nape (*nucha*); 8, hind neck (*cervix*); 9, side of neck; 10, interscapular region; 11, *dorsum* or back proper, including 10; 12, *notæum*, or upper part of body proper, including 10, 11 and 13; 13, rump (*uropygium*); 14, upper tail coverts; 15, tail; 16, under tail coverts; 17, tarsus; 18, abdomen; 19, hind toe (*hallux*); 20, *gastræum*, including 18 and 24; 21, outer or fourth toe; 22, middle or third toe; 23, side of the body; 24, breast (*pectus*); 25, primaries; 26, secondaries; 27, tertiaries, Nos. 25, 26, 27 are all *remiges*; 28, primary coverts; 29, *alula*, or bastard wing; 30, greater coverts; 31, median coverts; 32, lesser coverts; 33, the "throat," including 34, 37 and 38; 34, *jugulum*, or lower throat; 35, auriculars; 36, malar region; 37, *gula* or middle throat; 38, *mentum* or chin; 39, angle of commissure, or corner of mouth; 40, ramus of under mandible; 41, side of under mandible; 42, *gonys*; 43, *apex*, or tip of bill; 44, *tomia*, or cutting edges of the bill; 45, *culmen*, or ridge of upper mandible, corresponding to gonys; 46, side of upper mandible; 47, nostril; 48, passes across the bill a little in front of its face.—From Coues's Key.

calcareous shell ; there is an amnion and allantois, and no metamorphosis after hatching.

The external form of birds is very persistent ; the different parts of the body have been named in terms of continual use in descriptive ornithology. Hence, without entering into details, we reproduce from Coues's "Key" his figure of the topography of a bird.

The student, after a careful study of the external form, should prepare a skeleton of the common fowl, or examine one already at hand, and observe those characters peculiar to birds. The skull is formed of bones consolidated into a more roomy brain-box than in any reptiles, unless it be the Pterosaurians. In the parrots the beak of the upper jaw is articulated (Fig. 453, *n*) to the skull, so that the movement of the beak on the skull is unusually free. The quadrate bone (Fig. 453, *e*) is usually movable on the skull ; and in the parrots when the mouth opens the upper jaw rises, since when the mandible is lowered, the maxillo-jugal rod or bar (Fig. 453, *l*) pushes the premaxilla (22) upwards and forwards. This is a constant feature in recent birds, the degree of motion which this peculiar mechanism allows being variable.

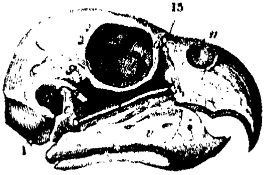

Fig. 453.—Skull of Parrot : 22, premaxillary bone ensheathed in horn ; 15, nasal bones ; *v*, mandible, the end sheathed with horn ; *l*, malo-squamosal zygomatic style or maxillo jugal bar ; *g*, post frontal bone ; *o*, lachrymal bone ; *n*, nostril, showing also the articulation of the naso-premaxillary bone ; *e*, quadrate bone ; *m*, orbit ; 1, occipital bone.—After Owen.

The form of a bird's vertebræ is peculiar to the class ; the articulation of the body (centrum) in all the vertebræ in front of the sacrum being saddle-shaped. "In *Strigops* and a few other land birds ; in the penguins, the terns, and some other aquatic birds, one or more vertebræ in the dorsal region are without the saddle-shaped articulation, and are either opisthocœlian, or imperfectly biconcave." (Marsh.) In the fossil *Ichthyornis*, which had a powerful flight, the vertebræ are bi-concave, as in fishes, and Amphibians, and a few reptiles ; but the third cervical shows an approach to the saddle-vertebræ of all other birds. The saddle form renders the articulation strong and free, and especially adapted to motion in a vertical plane. (Marsh.)

While the sternum of the cassowaries and other struthious birds (*Ratitæ*) is smooth, approaching that of reptiles, that of the higher living birds is keeled or carinate (Fig. 454, *crs*); hence these birds are called *Carinatæ;* to this keel and neighboring parts the muscles which raise and lower the wings are attached.

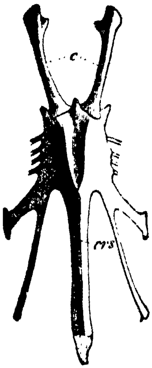

Fig. 454. Sternum of the Guinea Hen, seen from in front; *crs*, crest; *c*, coracoid bone.—After Gegenbaur.

The fore limbs of birds (Fig. 455) are greatly modified to form the framework of the wings. In spreading and closing the wings, the bones of the forearm slide along each other in a peculiar manner. (Coues.) The ulna is usually thicker and longer than the radius, and there are only two carpal bones, one radial, the other ulnar, in adult recent birds. The hand in the *Apteryx* and cassowaries has but one complete digit, while in other birds there are three digits, which probably correspond to the first, second, and third fingers of the human hand. The wings are attached to a strong shoulder-girdle, which consists of the two collar bones, uniting to form the wish-bone, and of a coracoid bone and scapula.

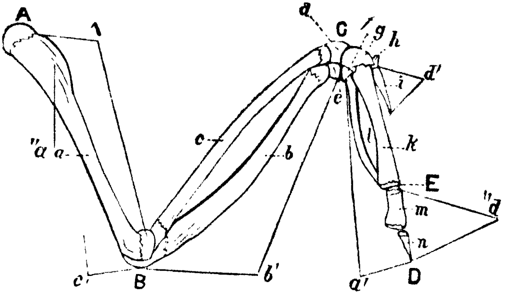

Fig. 455.—Right wing bones of a young Chicken. *A*, shoulder; *B*, elbow; *C*, wrist or carpus; *D*, tip of third finger; *a*, humerus; *b*, ulna; *c*, radius; *d*, scapholunar bone; *e*, cuneiform bone; *f*, *g*, epiphyses of metacarpal bones *l*, *k*, respectively; *h*, metacarpal and its digit *i*.—From Coues's Key.

The pelvis of birds is remarkable for the long slender backwardly projecting ischium and pubic bones; there is generally no bony union of the two pubic bones, nor do the ischia unite with the sacrum or each other, except in *Rhea*. In the ostrich, the pubic bones are solidly united. The hind limbs (Fig. 456) are two, three, or four toed, the ostrich having but two digits; in most four-toed birds, one toe (the hallux) is directed backwards, while in the parrots and trogons, etc., there are two toes in front and two toes behind, and in the swifts and certain other forms all four toes are turned forwards. The bones of the skeleton are dense and hard; both the long bones and the bones of the skull are commonly hollow, containing air; the air-sacs, in connection with the lungs, communicating with the hollows of the bone. In some birds which fly well, only the skull-bones have air-cells, while in the ostrich which is unable to fly, the bones have even a greater number of cavities than the gull. The body during flight is thus greatly lightened, and the bird can sustain itself in the air for many hours in succession.

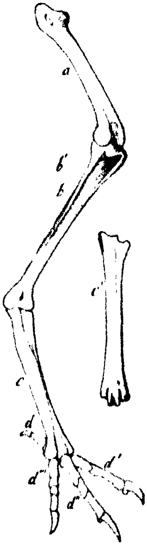

Fig 456.—Hind limb of a Hawk, *Buteo vulgaris*. *a*, femur; *b*, tibia; *b'*, fibula; *c*, tarso metatarsus; *c'*, the same piece isolated, and seen from in front; *d d'*, *d''d'''*, the four toes.—After Gegenbaur.

With all these characters, the most remarkable and diagnostic external feature is the presence of feathers; no reptile on the one hand, or mammal on the other, is clothed with feathers, though the scales on the legs and feet of birds are like those of reptiles, and it should be borne in mind that feathers are fundamentally modified scales or hairs. The ordinary feathers are called pennæ or contour feathers; as they determine by their arrangement the outline of the body. They are, like hairs, developed in sacs in the skin; the quill is hollow, partly imbedded in the derm; this merges into the shaft, leaving the outgrowths on each side called *barbs*, which send off secondary processes called *barbules*. These tertiary processes (called barbules and hooklets) are commonly serrated, and end in little hooks by which the barbules interlock. Down is formed of feathers with soft, free barbs, called plumules. Over the tail-bone (*coccyx*) are usually sebaceous glands, which secrete an oil, used by the bird in oiling and dressing or "preening" its feathers. In some birds, especially in the males of the gallinaceous fowls, as the cock and turkey, the head and neck are ornamented with naked folds of the skin called "combs" and "wattles."

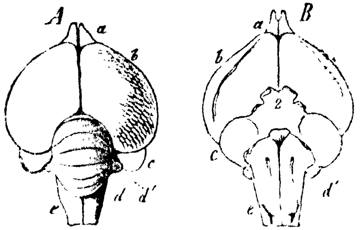

Fig. 457.—Brain of the Hen. *A*, from above, *B*, from below; *a*, olfactory bulbs, *b*, cerebral hemispheres; *c*, optic lobes; *d*, cerebellum; *d'*, its lateral parts; *e*, medulla.—After Carus, from Gegenbaur.

The brain is much larger than in the reptiles, the cerebral hemispheres being greatly increased in size, while the cerebellum is transversely furrowed, and is so large as to cover the whole of the medulla. The alimentary tract consists of an œsophagus as long as the neck; it dilates in the domestic fowl and other seed-eating birds, as well as in the raptorial birds, into a lateral sac called the crop (*ingluvies*). The stomach is divided into two parts, the first, the *proventriculus*, which is glandular, secreting a digestive fluid; and the second, which corresponds to the pyloric end of the stomach in the mammals, is round, with muscular walls, especially developed in seed-eating birds, and called the "gizzard." In the fowl the gizzard is lined with a firm horny layer, by which the food is crushed and comminuted, thus taking the place of teeth. The intestine (including the large and small intes-

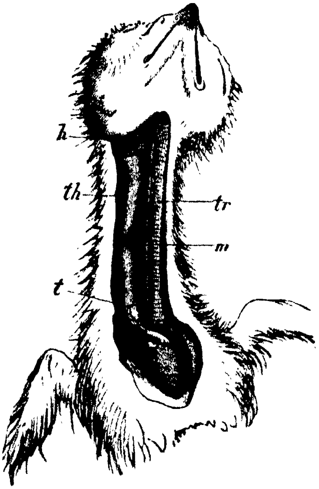

Fig. 458.—Thymus (*th*) and thyroid (*t*) glands of a young hawk, *Buteo vulgaris* of Europe; *tr*, trachea.—After Gegenbaur.

tine) is long and ends in a cloaca, which receives the ends of the urinary canals and oviducts. Attention should be given to the trachea; its bronchial branches, the larynx and the *syrinx* or lower larynx, which may be developed either at the end of the trachea, or at the junction of the trachea and bronchi, or in the bronchi alone. The thymus gland (Fig. 458, *th*) is very large and long, while the thyroid (*t*) is a small, oval mass situated at the beginning of the bronchi.

The following account and drawings of the anatomy of the pigeon have been prepared from original dissections by Dr. C. S. Minot. As pigeons are one of the most readily obtainable and convenient types of birds, the following description of the anatomy of a male is given as illustrative of the class, those peculiarities being especially noticed by which birds are distinguished from reptiles and mammals.

Before dissecting a bird, it must be carefully plucked; this operation is much facilitated by dipping the animal in boiling water for a few minutes. The limbs and muscles of one, best of the left, side are to be removed; the powerful pectoral muscles cut off close to their attachment to the keel of the breast-bone, and the ribs then cut away, care being taken to avoid injuring any of the internal organs, most of which will now be displayed *in situ* nearly as shown in Fig. 459, which represents a dissection carried somewhat further.

The skin (Fig. 459, *E*, from the neck) is characterized by the presence of numerous ridges which cross one another, so as to enclose quadrilateral spaces; at the intersections of the ridges are small pits in which the feathers are inserted.

The digestive canal begins in the horny bill with three openings, one the large gape or mouth, and two oblique elongated nasal clefts (*n*), through which respiration is ordinarily alone effected. It then extends backward underneath the base of the skull, where it splits into the œsophagus and trachea, two large tubes which run down the front of the neck, the œsophagus on the right and the trachea on the left. Just below the head the trachea lies, in its normal position, in front of the œsophagus, though in most adult birds both tubes follow a symmetrical course, but exhibit a mock or secondary symmetry with regard to each other. The origin of the two canals is embraced by the hyoidean apparatus, one of the horns (*cornua*) of which appears at *Hy*; the apparatus is too complicated to be described here; it closely resembles that of reptiles, and is functionally connected with the rapid thrusting out of the tongue. In some birds, as, for example, the woodpeckers and humming-birds, the horns are so developed as to curve round the back of the cranium on to the top of the skull. (Fig. 474).

The trachea (*Tr*) is composed of cartilaginous rings with intervening membranes, and an external sheath of connective tissue, which has been removed at *Tr*. It extends into the thorax, and is of nearly uniform diameter throughout, except at its lower extremity, where, as shown in Fig. 459, *D*, it forms an enlargement, the syrinx or vocal chamber (*L*), found only in birds, but wanting in the ostrich, etc. (*Ratitæ*), storks, and certain birds of prey. The trachea terminates immediately behind the syrinx in two smaller branches, the bronchi (*B*), each of which passes into the lung (*Lu*) of the same side. The cartilaginous rings of the bronchi are incomplete, the walls being partly formed by an elastic membrane. The rings of the trachea are peculiarly modified in the syrinx, which is furnished with external muscles and internal membranous expansions, serving to produce the voice; the muscles are the sterno-tracheal, furculo- or claviculo-tracheal, and the proper muscles of the syrinx. A true larynx is present in the upper part of the trachea, but is unessential to the formation of the voice. The trachea presents flexuosities in various birds, usually more marked in the male than in the female; in swans there is a great band which extends into the hollow breast-bone, but the object of this disposition is unknown.

The lungs (Fig. 459, *Lu*) are two large sacs, placed dorsally in the anterior part of the body-cavity, but not suspended freely in a short thoracic sac nor enclosed in a pleura, as in mammals; they are composed of reddish spongy tissues, and are attached between the ribs by connective tissue.

Each lung has upon its outer and dorsal surface five transverse depressions, corresponding to as many ribs. The bronchi and pulmonary blood-vessels enter together the anterior third of the lungs, and follow one another in their ramifications, but the bronchus traverses the lungs, giving off numerous branches, and opens into the abdominal air-sac, while upon the surface of the lungs there are small openings communicating with the remaining air-sacs. These structures the student had best tear through and altogether neglect in his first dissection. The air-sacs are thin-walled bags, nine in number: three near the clavicle, four in the thorax, and two in the abdomen; their ramifications extend even into the bones, most of which are accordingly found to be hollow. This striking organization is one of the most characteristic peculiarities of birds, and serves to lighten the body by filling large spaces with warm air, besides fulfilling certain other less obvious functions. In many chameleons and some Geckos the lungs have diverticula or offshoots, which foreshadow the air-sacs of birds.

The alimentary canal consists of seven parts: the œsophagus, crop, glandular and muscular stomachs, large and small intestines, and cloaca. The œsophagus extends about three fifths of the way down the right side of the neck, and is approximately of the same diameter as the trachea, with regard to which, as before mentioned, it lies symmetrically. It opens into the crop (*Cr*), a thin-walled sac, which fills the triangular space between the base of the neck and the keel of the sternum, and forms a large part of the curved outline of the breast. In the specimen figured, the left half of the crop has been removed to show the irregular folds upon the inner surface, the deep lateral pouch and the three posterior longitudinal folds of one side, which serve to guide the food onward to the stomach. As shown in Fig. 459, *D*, the crop (*Cr*) ends just to the right of and above the trachea, in a dorsally-placed, narrow tube, that reaches to the origin of the bronchi, and there gradually expands into the glandular stomach, which cannot, however, be seen in a general dissection, while the heart, lungs, and liver are still *in situ.* The muscular stomach or gizzard (*St*) of the main figure is represented very large, being distended with food; it is sometimes found much contracted; it is not sharply separated from the glandular stomach, the two being in reality only the greatly modified anterior and posterior divisions of the same dilatation. The opening of the glandular stomach and the origin of the small intestine are near together upon the anterior border of the gizzard. The walls of this last organ are remarkable for the enormous development of the muscular layers, especially in the graminivorous birds, under which pigeons are to be included; the muscles radiate on each side from a central tendinous space. The small intestine has numerous coils, in the first of which lies the pancreas (*Pan*), very much as in mammals. The large intestine (*R*) is relatively short; its commencement is marked by two small diverticula, distinctive of birds.* These appendages are well developed in some species, as, for instance, the *Gallinaceæ*, while in the bustard they have been described as three feet long. Gegenbaur considers the œsophagus, crop, and stomach to be derived from the fore-gut, the small intestine from the mid-gut, and the large intestine from the hind-gut of the embryo. The cloaca (*Cl*) is the short and widened termination of the alimentary canal, and further receives four ducts, the two ureters (*Ur*), and in the male the two *vasa deferentia* (*Vd*), in the female the two oviducts.

The digestive canal has two glandular appendages, the pancreas (*Pan*) and the liver (*Li*); the former, as in birds generally, is quite large, whitish, and sends out a prolongation, which extends to the spleen; it has two ducts. The liver (*Li*) is very voluminous, dark reddish brown in color, and forms two lobes, which rest upon the apex of the heart and the gizzard, and conceal the glandular stomach. There is no gall-bladder, a somewhat unusual feature among birds, but there are two bile-ducts, the larger and shorter opening into the upper part, while the longer duct, after uniting with that of the pancreas, opens into the lower part of the duodenum.

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* Some snakes have a single diverticulum, as is said to be the case with herons.

The length of the neck in birds is never less than the height at which the body is carried from the ground; the number of vertebræ entering into its formation varies from 9 to 24 (swan); in the pigeon there are twelve, accompanied by a corresponding number of spinal nerves, the branches of which may be observed immediately underneath the skin. The main mass of the neck is composed of the vertebral column and muscles, the trachea and œsophagus. On either side of the base of the neck, in close proximity to the trachea and carotid artery, is a small oval white body, the thyroid gland (*Tr*), at first developed as an evagination of the fore-gut, but afterward becoming a closed and ductless sac, which is found in the majority of vertebrates, but the use of which to the organism is entirely unknown. Above the thyroid lie the carotid artery and jugular vein, the main vascular trunks of the head and neck. The right jugular vein is usually the largest. Along the side of the neck, above the trachea on the left and the œsophagus on the right, lies the elongated thymus gland (*Tm*), drawn somewhat diagrammatically; this gland forms part of the lymphatic system, and in minute structure resembles the spleen.

The heart (*Ht*) lies immediately below the lungs and against the sternum, with its apex between the two lobes of the liver pointing obliquely downward and backward; it is enclosed in a thin membranous bag, the pericardium, which is filled with serous fluid and attached to the roots of the main vascular trunks. To study the heart, it must be excised, taking the greatest care to leave as much as possible of the vessels, especially the large veins behind, in connection with it. Viewed from behind (Fig. 459, *C*), the heart is seen to be composed of four chambers, the two anterior ones, the auricles, being the smaller. The left auricle receives upon its dorsal side the opening of the united pulmonary veins (*Pv*), one from each lung; the right auricle is larger than the left, and receives in its upper portion the right *vena superior* (*Vsd*); in its lower portion the left *vena* *cava superior* (*Vs*), just above which opens the *vena cava inferior* (*Vi*). The two larger and posterior chambers, the ventricles, form the apex of the heart, and give off the arterial trunks. Of the ventricles, the left (*Ven. s*) is the largest, has the thickest walls, and alone extends to the apex of the heart; it gives off the aorta, a short trunk which divides into a right and left branch, from which spring the carotid arteries for the head and neck, and which continue as the subclavian or auxiliary arteries *A* and *A'* for the wings. From the base of the right branch *A* arises the large aorta (*Ao*), which turns around the bronchus of the same side, and runs to the front and right of the vertebral column through the abdomen, forming the descending aorta which gives off arteries to the intercostal and lumbar regions and to the viscera, and terminates in a *crural* branch to each leg. The right ventricle (*Ven. d*) has much thinner walls than the left; from it arises the pulmonary aorta (*Pa*) which soon branches to each side.

Birds are distinguished from reptiles by having a four-chambered heart and a single permanent aortic trunk; from mammals by the persistence of the right instead of the left aortic arch to form the aorta. Each auricle communicates with the ventricle of the same side; the connecting orifices are furnished with valves. The right auriculo-ventricular valve is muscular in all birds, while the left is membranous.

The uro-genital organs lie dorsally in the hinder part of the body-cavity. The dark reddish brown kidneys (*Ki*) consist, as in most birds, each of three lobes, the posterior being the largest; they lie immediately behind the lungs. The ureters (*Ur*) are slightly curved, whitish tubes, which pass back from the kidneys and open into the dorsal side of the cloaca. The testicles (*Te*) are two large oval whitish bodies, each situated immediately behind the lung and below the kidney of the same side. The *vasa deferentia* (*Vd*) arise from the anterior and inner surfaces of the testicles, have a flexuous course, and, after forming terminal enlargements, open separately into the cloaca, in front of the ureters. In neither sex in birds are the genital ducts provided with accessory glands.

As usual among birds, the head is approximately top-shaped. The eyes are very large and much exposed, as becomes evident upon dissecting off the skin as in the figure. The external ear is a mere circular opening, entirely covered during life by the feathers. The side of the cranium may be removed so as to expose the brain, with the large smooth cerebral hemispheres (*C*), the convoluted cerebellum (*Cb*), and the much smaller medulla (*Md*). To study the brain satisfactorily, it must be removed from its case. A view of it from the side is given in Fig. 459, *A*, and a view from above in the same figure at *B*. The *medulla oblongata* (*M*) appears as hardly more than the enlarged upper end of the spinal cord: upon its dorsal surface there is a triangular depression IV, the fourth ventricle, which is partially concealed by the *cerebellum* (*Cb*), a large mass marked by transverse ridges and imperfectly divided into three lobes, thus exhibiting, both in its size and its complication of structure, a great advance over the reptiles. The *corpora quadrigemina* or *bigemina** (*Q*) project as two large lobes far out on the sides and down the base of the brain; their position and great size are characteristic for the whole class. The *optic thalami*, which intervene between the bigemina and the hemispheres, are relatively small; they enclose the third ventricle and have a funnel-shaped downward extension, to which the pituitary body is attached, as to a stalk. The *cerebral hemispheres* (*He*) form more than half of the whole brain; their surfaces are entirely without convolutions, but each hemisphere has a small projection, the olfactory lobe (*Ol*), upon its anterior and inferior extremity. The cavities of the hemispheres or the lateral ventricles are very large and extend also into the olfactory lobes. The greatly thickened inferior walls of the hemispheres are termed the *corpora striata*. Birds differ from mammals in having only a rudimentary *fornix* and no *corpus callosum*. The description of the cranial nerves is purposely omitted.

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* Also called the optic lobes, middle brain, and mesencephalon.

Between the liver and the glandular stomach lies the small, somewhat elongated, reddish brown spleen.

In birds, as in most vertebrates, several spinal nerves unite to form a brachial plexus, part of which is shown at *B*, and which supplies the wings. Posteriorly, there is also formed a plexus, the lumbar, for the legs.

The muscles of the limbs are much modified in accordance with the peculiar locomotion of birds. In connection with the power of flight, the sternum has a very large keel, to which are attached the pectoral muscles. The *pectoralis major* (*Pc*) is the most external; it arises from the outer half of the keel and is inserted into the humerus, and effects the downward stroke of the wing. The second pectoral (*pectoralis tertius* of some authors and the homologue of the comparatively insignificant subclavius of human anatomy) arises from the inner portion of the keel, runs forward and outward, and, tapering off, passes through a groove between the coracoid and sternum, as over a pulley, to be inserted into the humerus. The wing is raised by its action. In the ostrich, etc. (*Ratitæ*), the breast-bone has no keel, and the disposition of the muscles of the rudimentary wings therefore differs greatly from that here described. (Minot.)

The ovary may be distinguished by the large incipient eggs forming the greater part of the mass. The right ovary is usually undeveloped, but when partly formed, as in some hawks, the eggs do not mature.

The " white" is deposited around the true egg in the upper part of the oviduct, while the shell is secreted from glands emptying into the lower part of the duct. The eggs of birds are enormous in proportion to those of other vertebrate animals, except the lizards. The egg of the *Æpyornis*, an extinct bird of Madagascar, is about a third of a metre (13½ inches) in length, and as the egg is in reality a cell, this is the largest cell known. The development of the chick is better known than that of any other animal. It travels the same developmental path as other vertebrates in which an amnion and allantois are formed. About the sixth day of embryonic life the bird-characters begin to appear, the wings begin to differ from the legs, the crop and giz-

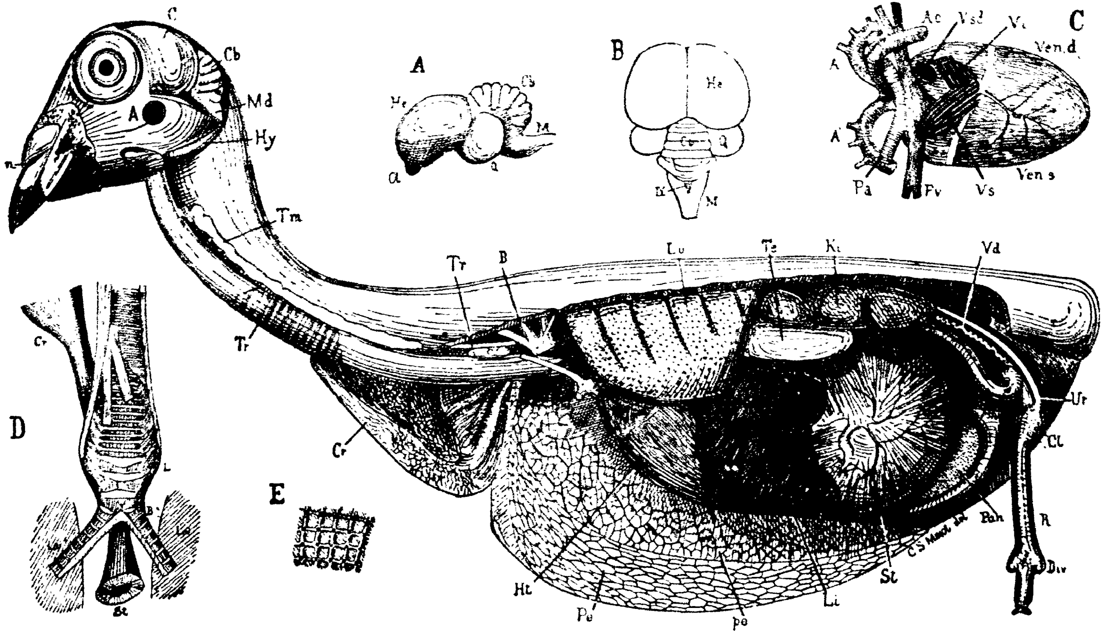

Fig. 459.—Anatomy of the Pigeon. A, B, brain; C, heart; D, syrinx and bronchi; E, skin.—Drawn by C. S. Minot.

zard are indicated, and the beak begins to develop. By the ninth or tenth day the feathers originate in sacs in the skin, these sacs by the eleventh day appearing to the naked eye as feathers ; the nails and scales of the legs and toes are marked out on the thirteenth day, and by this time the cartilaginous skeleton is completed, though the deposition of lime (ossification) begins on the eighth or ninth day by small deposits of bone in the shoulder-blade and limb-bones ; centres of ossification appearing in the head by the thirteenth day.

"After the sixth day, muscular movements of the embryo probably begin, but they are slight until the fourteenth day, when the embryo chick changes its position, lying lengthways in the egg, with its beak touching the chorion and shell membrane, where they form the inner wall of the rapidly increasing air-chamber at the broad end. On the twentieth day or thereabouts, the beak is thrust through these membranes, and the bird begins to breathe the air contained in the chamber. Thereupon the pulmonary circulation becomes functionally active, and at the same time blood ceases to flow through the umbilical arteries. The allantois shrivels up, the umbilicus becomes completely closed, and the chick, piercing the shell at the broad end of the egg with repeated blows of its beak, casts off the dried remains of allantois, amnion, and chorion, and steps out into the world." (Foster and Balfour.)

Some young birds have, as in turtles and snakes, a temporary horny knob on the upper jaw, used to crack the shell before hatching. In birds which lay small eggs, with a comparatively small yolk, the young are brooded in nests and fed by the parent ; but in the hen and other gallinaceous birds, in the wading birds and many swimmers, as ducks, where the yolk is more abundant, the young maintain themselves directly on hatching.

Following the business of reproduction is the process of moulting the old and weather-beaten feathers. This is often a critical period in a bird's life, judging by the occasional mortality among domesticated and pet birds. The annual moulting begins at the close of the breeding season, though some birds moult twice and thrice. The quill-feathers (remiges) are usually shed in pairs, but in the ducks (*Anatidæ*) they are shed at once, so that these birds do not at this time go on the wing, while the males put off the highly-colored plumage of the days of their courtship, and assume for several weeks a dull attire. In the ptarmigan both sexes not only moult after the breeding season is over into a gray suit, and then don a white winter suit, but also wear a third dress in the spring. In the northern hemisphere the males of many birds put on in spring bright, gay colors. Other parts are also shed: for example, the thin, horny crests on the beak of a western pelican (*Pelicanus erythrorhynchus*), after the breeding season, are shed like the horns from the head of deer. Even the whole covering of the beak and other horny parts, like those about the eyes of the puffin, may also be regularly shed. The variations in the frequency, duration, and completeness of the process are endless.

As a rule, male birds are larger and have brighter colors, with larger and more showy combs and wattles than the females, as seen in the domestic cock and hen; and the ornamentation is largely confined to the head and the tail, as seen especially in male humming-birds. Mr. Darwin has adduced a multitude of examples in his Descent of Man, Vol. 2. Sometimes, however, both sexes are equally ornamented, and in rare cases the female is more highly colored than the male; she is sometimes also larger, as in most birds of prey. There is little doubt that the bright colors of male birds render them more conspicuous and to be more readily chosen by the females as mates, for in birds, as in higher animals, the female may show a preference for or antipathy against certain males. Indeed, as Darwin remarks, whenever the sexes of birds differ in beauty, in the power of singing, or in producing what he calls "instrumental music," it is almost invariably the male which excels the female.

The songs of birds are doubtless in part sexual calls or love-notes, though birds also sing for pleasure. The notes of birds express their emotions of joy or alarm, and in some cases at least the notes of birds seem to convey intelligence of the discovery of food to their young or their mates. They have an ear for music; some species, as the mocking-bird, will imitate the notes of other birds. The songs of birds can be set to music. Mr. X. Clark has published in the *American Naturalist* (Vol. 13, p. 21) the songs of a number of our birds. The singular antics, dances, mid-air evolutions, struts, and posturings of different birds, are without doubt the visible signs of emotions which in other birds find vent in vocal music.

The nesting habits of birds are varied. Many birds, as the gulls, auks, etc., drop their eggs on bare ground or rocks; as extremes in the series are the elaborate nests of the tailor-bird, and the hanging nest of the Baltimore oriole, while the woodpecker excavates holes in dead trees. As a rule, birds build their nests concealed from sight; in tropical forests they hang them, in some cases, out of reach of predatory monkeys and reptiles. Birds may change their nesting habits sufficiently to prove that they have enough reasoning powers to meet the exigencies of their life. Parasitic birds, like the cuckoo and cow-birds, lay their eggs by stealth in the nests of other birds.

The duties of incubation are, as a rule, performed by the female, but in most Passerine birds and certain species of other groups, the males divide the work with the females, and in the ostrich and other *Ratitæ* the labor is wholly performed by the males.

There are probably from 7000 to 8000 species of living birds; Gray's "Handlist" enumerates 11,162, but many of these are not good species. Of the whole number, about 700 distinct species or well-marked geographical races inhabit North America north of Mexico. The geographical distribution of birds is somewhat complicated by their migrations. While the larger number of species are tropical, arctic birds are abundant, though most of them are aquatic. In the United States there are three centres of distribution: (1) the Atlantic States and Mississippi Valley; (2) the Rocky Mountain plateau, and (3) the Pacific coast. The migrations of birds will be treated of near the close of this volume.

While in former times existing birds were divided into a large number of "orders," these are now known to be subdivisions of the two sub-classes *Ratitæ* and *Carinatæ*, and probably in many cases should be honored only with the rank of sub-orders. The discovery of the *Archæopteryx* and of birds with teeth and biconcave vertebræ has essentially modified prevailing views as to the classification of birds.

Sub-class 1. *Saururæ.*—The oldest bird, geologically speaking, is the *Archæopteryx* (Fig. 460) of the Jurassic slates of Solenhofen, Germany. This was a bird about the size of a crow, the tail being 22 cent. (8–9 inches) long, but longer than the body, supported by many movable vertebræ and covered with feathers in distichous series, not in the shape of a fan. The jaw-bones were long, and contained conical teeth. The head, shoulder girdle, and fore limbs, with their three digits, were reptilian in form. (Vogt.) In these respects and in the long tail the creature served as a connecting link between the reptiles, such as the bird-like *Compsognathus*, and the existing birds. The hind legs and wings have the ordinary bird structure, though the metacarpal bones were not co-ossified: the foot consisted of three digits.

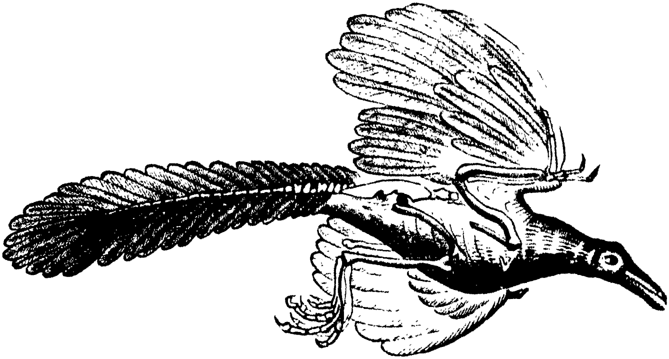

Fig. 460.—Restoration of *Archæopteryx macrura*.—After Owen, from Nicholson.

Sub-class 2. *Odontornithes.*—Still another connecting link between the reptiles and birds has been discovered by Marsh in the upper Cretaceous beds of this country. The remains of *Ichthyornis* indicate an aquatic bird about the size of a pigeon. The reptilian affinities are seen in the vertebræ, which, unlike those of all other birds, are biconcave, and in the long, slender jaws, with stout, conical teeth held in sockets, as in the crocodiles. On the other hand, the wings were well developed, and the legs were of the ordinary bird type, the metacarpal bones being co-ossified, while the sternum was keeled. In a second member of the group (*Hesperornis*) the teeth were in grooves, the vertebræ as in recent birds, the sternum without a keel, and the wings were rudimentary (Marsh).

Sub-class 3. *Ratitæ.*—This group, represented by the kiwi-kiwi, the moa, cassowary, and ostrich, is characterized by the smooth unkeeled sternum and the short tail; the wings are rudimentary and the hind legs strong, these birds (except *Apteryx*) being runners, and either of large or, as in the extinct forms, of colossal size.

The simplest form is the "kiwi-kiwi," or *Apteryx* of New Zealand (Fig. 461), of which there are three or four species. It is of the size of a hen, with a long slender beak, the nostrils situated at the end of the upper jaw, while the body is covered with long hairy feathers. The female lays only a single large egg, which weighs one quarter as much as the bird itself, in a hole in the ground. It is a night bird, hiding by day under trees.

The giant, ostrich-like, extinct birds of New Zealand, called *moa*, and represented by several species, chiefly of the genera *Dinornis* and *Palapteryx* (Fig. 461), were supposed to have been contemporaries of the Maoris or natives of New Zealand. While a fourth toe (*hallux*) is present in the *Apteryx*, the moa-bird has only three toes.

The largest of the moas, *Dinornis giganteus* of Owen, stood nearly three metres (9½ feet) in height, the tibia or shin-bone alone measuring nearly a metre (2 feet 10 inches) in length. These moa birds belong to three genera: *Dinornis* with ten, *Palapteryx* with three, and *Aptornis* with a single species.

Allied to the moa was a still larger bird, the *Æpyornis* *maximus*, of Madagascar, supposed by some to be the roc of the Arabian Nights' Tales. Of this colossal bird, remains of the skull, some vertebræ, and a tibia 64 cent. long, have been found. The single egg discovered is of the capacity of one hundred and fifty hens' eggs.

To this order belong the three-toed cassowaries of the East Indies and Australia, and the emeu of Australia; both of these birds are about 2 metres (5–7 feet) high. The South American ostrich (*Rhea Americana*) with three toes to each foot, is a smaller bird, standing 1·3 metres high, running in small herds on the pampas. The two-toed ostrich (*Struthio camelus* Linn.), of the deserts of Africa and Arabia, now reared for the feathers of its wings and tail, so

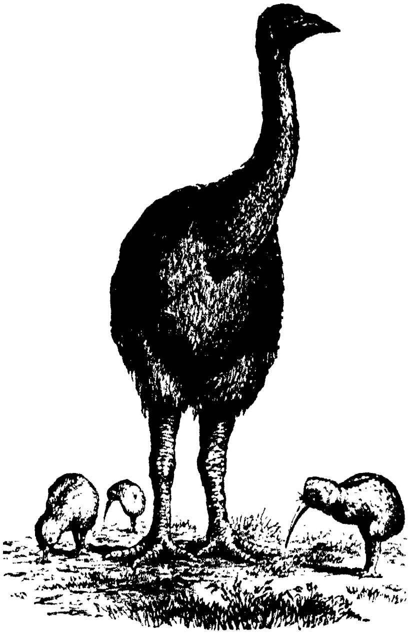

Fig. 461.—Moa, *Palapteryx*, with three Kiwi-kiwi birds.—After Hochstetter, from Tenney's Zoology.

valuable as articles of commerce, is the largest bird now living, being 2–2·7 metres (6–8 feet) high. It can outrun a horse, and lives in flocks. It lays about thirty large white eggs in a nest in the sand ; they are covered in the daytime by the hen or left exposed to the sun, while at night the male sits over and guards them. In Cape Colony, ostrich-culture has become an important business ; in 1865 there were only eighty individuals on the ostrich farms ; in 1875 there were 32,247 ostriches, either free or in parks where Lucerne grass is cultivated as food for these useful birds. The South American ostrich is in Patagonia hunted for its feathers. During the Eocene Tertiary period a gigantic ostrich-like bird (*Diatryma* Cope), twice as large as

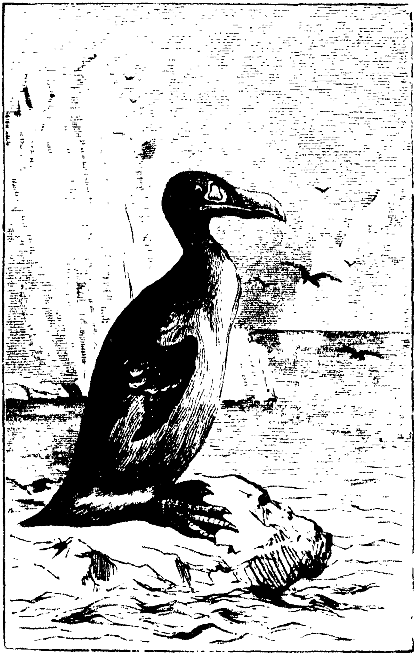

Fig. 462.—Great Auk.—From Coues' Key.

an ostrich, lived in Texas and New Mexico, part of a leg-bone having been found on the San Juan River.

Sub-class 4. *Carinatæ.*—All other living birds belong to this group; they are remarkably homogeneous in form and structure, and the subdivisions may be regarded as orders. They are characterized by the keeled breast-bone or sternum—the wings, as a rule, being well developed.

The diving birds (*Pygopodes*) are eminent as swimmers, and comprise the penguins, auks, puffins, grebes, and loons. The penguins are confined to the antarctic regions. They are large birds, and form a characteristic element in a Patagonian landscape. The bones are solid, not light and hollow, as in other birds; the wings are small, paddle-like, with scale-like feathers; on shore they have an awkward gait. They lay but a single egg, and some species do not lay their egg on the rocks, but bear it about in a pouch-like abdominal fold. The penguins, however, differ so much from the other divers that they are now often ranked as a separate group of this grade, called *Sphenisci.*

The guillemots and auks are characteristic arctic birds ranging from Labrador northward, and have great powers of flight. The gare fowl, or great auk (*Alca impennis*, Fig. 462), is nearly or quite extinct, being until lately confined to one or two inaccessible islets near Iceland, where it has been extinct since 1844, and to Labrador, though formerly it ranged from Cape Cod northward, a few survivors having lived on the Funks, an islet on the eastern coast of Newfoundland, within perhaps thirty years.

The loons are well known for their large size and quickness in diving. They are migratory, laying two or three eggs in rushes near the water's edge.

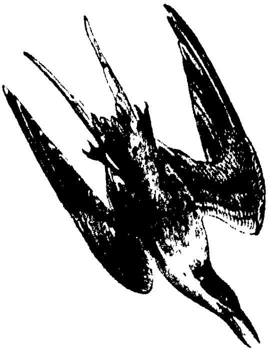

Fig. 463. Roseate Tern. From Tenney's Zoology.

The petrels, gulls, and terns (Fig. 463, roseate tern) represent the group of long-winged swimmers (*Longipennes*). They have long, slender, compressed bills, long, sharp wings, immense powers of flight, and lay their eggs in rude nests on rocks or upon the ground. The most notable member of the group is the albatross (*Diomedea exulans*) of the Southern hemisphere. Its wings expand more than three metres (nearly ten feet). It lays a single egg 12 cm. long, and spends most of its life on the ocean far away from land. The sooty albatross (*D. fuliginosa* Lawrence, Fig. 464), is occasionally seen on our coast.

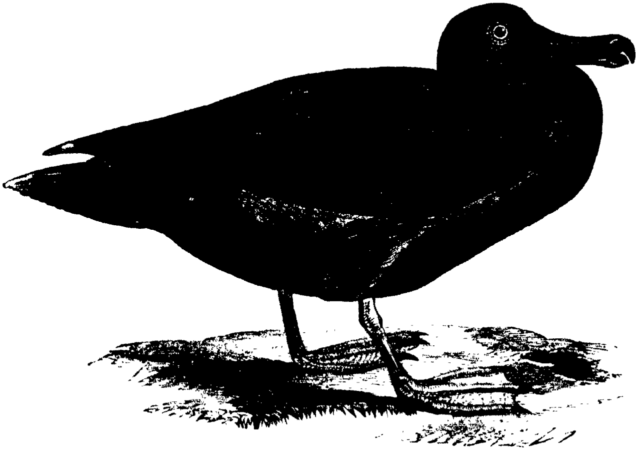

Fig. 464.—Sooty Albatross.—From Coues' Key.

These birds are succeeded in the ascending series by the tropic-bird, frigate or man-of-war bird, the darter or snake-bird, the cormorants, pelicans, and gannets (*Steganopodes*), in which all four toes are fully webbed, the web reaching to the tips of the toes. The body, especially in the pelicans and gannets, is buoyed up more than in other birds by a large number of much subdivided air-cells under the subcutaneous areolar tissue of the body.

The pelican is remarkable for the large, loose pouch on the under jaw, capable of holding several quarts, or several hundred small fishes. In the East Indies, pelicans are tamed and used by the natives in fishing, as is the cormorant in China, while in early times it was in England.

The ducks and geese (*Lamellirostres*) have usually broad bills furnished with lamellate, teeth-like projections. The feet are palmated, adapted for swimming rapidly. In the mergansers the bill is narrow and more strongly toothed. The eider duck (*Somateria mollissima*) breeds from Labrador around northward to Scotland, plucks its down from its breast, building with it a large loose warm nest under low bushes on the sea-coast, where it lays three or four pale dull green eggs. The canvas-back (*Fuligula vallisneria*) feeds, as its specific name implies, on the wild celery (*Vallisneria*) on the middle Atlantic coast in winter, whence it derives its delicious flavor. The summer duck (*Aix sponsa*, Fig. 465) breeds in trees. The original source of our domestic duck is the mallard, or *Anas boschas*. It is known to cross with various other species. Upward of fifty kinds of hybrid ducks are recorded, some of which have proved to be fertile (Coues). The black duck (*Anas obscura*) is abundant on the shores of Northeastern America, and is fre-

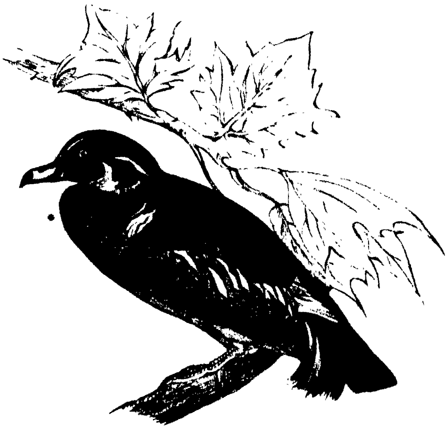

Fig. 465.—Summer Duck.—From Coues' Key.

quently brought into the market. The wild goose (*Branta Canadensis*) breeds in the Northern United States and in British America. While it usually breeds on the shores of rivers, it has been known in Colorado and Montana to nest in trees. Allied to it is the barnacle goose of Europe (*Branta leucopsis*), which very rarely occurs in this country. The swans are characterized by their long necks, the trachea or wind-pipe being remarkably long, especially in the trumpeter swan, where it enters a cavity in the breast-bone, makes a turn and enters the lungs, after forming a large coil.

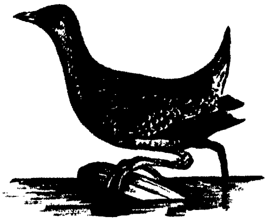
Fig. 466.—Carolina Rail.—From Coues' Key.

To this group, or next to it, also belong the flamingoes, the American flamingo (*Phœnicopterus ruber*) occurring on the Florida and Gulf coast. Its feathers are scarlet, its bill yellow, large and thick, while the legs and neck are of great length. It connects the swimming with the wading birds. The foregoing group forms a division called the *Natatores* or swimming birds. We now come to the *Grallatores* or wading birds, which have long, naked legs, and therefore long necks, with usually remarkably long bills. They are divided into cranes, rails, etc. (*Alectorides*), the herons and their allies (*Herodiones*), and the shore-birds, snipes and plovers, or *Limicolæ*.

The cranes, together with rails (*Porsana Carolina*, Fig. 466) sometimes have lobate feet, the toes are often long, and in some forms, such as the coots and gallinules, there is an approach to the ducks.

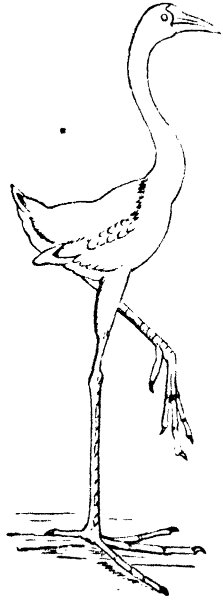
Fig. 467.—The "Giant" of Mauritius.—After Schlegel.

Allied to the gallinules is the "giant" or *Gallinula* (*Leguatia*) *gigantea* of Schlegel (Fig. 467), which formerly lived in the Mascarene Islands, having been observed as late as 1694. It stood two metres (over six feet) high. With it was associated a large blue gallinule—*Porphyrio* (*Notornis?*) *cœrulescens* Selys—which was last seen on the Isle Bourbon between 1669 and 1672. It was incapable of flight, but ran with exceeding swiftness.

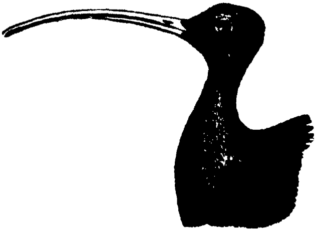

Fig. 468.—Long-billed Curlew.—From Coues' Key.

The cranes are of great stature, the legs and neck very long, with the head sometimes curiously tufted. With the true herons are associated the night herons and the bitterns of the United States, the boat-billed heron of Central America, and the odd *Balœniceps rex* of Africa, which has an enormous head and broad, large bill. The herons are succeeded by the singular spoon-bills represented by the roseate spoon-bill, and which, with the wood Ibis and other species of this group, adorn the swamps and bayous of the South Atlantic and Gulf States.

The shore-birds, or the curlews (*Numenius longirostris*, Fig. 468), plover, sandpipes, peeps, snipes (*Gallinago Wilsonii*, Fig. 469), woodcock, and stilt (*Himantopus nigricollis*, Fig. 470), are long-legged, long-billed birds, going in flocks by the seashore or river-banks, sometimes living inland on low plains; they are not, generally speaking, nest-builders, the eggs being laid in rude nests or hollows in the ground. They feed on worms, insects, and snails, either picking them up from the surface or boring for them in the mud or

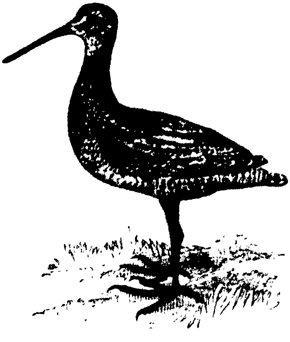

Fig. 469.—American Snipe.—From Coues' Key.

sand, or forcing the vermian food out of their holes by stamping on the ground.

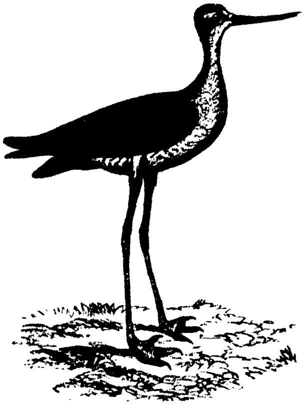

Fig. 470.—Stilt.—From Coues' Key.

Connecting in some degree the waders and gallinaceous fowl are the bustards of the Old World, certain strange exotic birds, especially the horned screamers represented by a very rare bird, the *Palamedea cornuta* Linn., which has sharp horns on the wings.

The form of the gallinaceous birds, formerly called *Rasores*, from their peculiar habit of scratching the ground for food, is readily recalled by a simple enumeration of the partridge, Oreortyx (*O. pictus*, Fig. 471), quail (*Ortyx*), ptarmigan (*Lagopus*, Fig. 472), pinnated grouse or prairie hen (*Cupidonia cupido*), sage-cock, Canada grouse or spruce partridge (*Tetrao*), and wild turkey (*Meleagris*), as well as the exotic forms, the pheasant of the Old World, the useful hen or barn-yard fowl, which is a descendant of *Gallus Bankiva* Temminck, of India. These are allied to the argus-pheasant and the peacock, the latter rivalling the humming-birds in its gorgeous plumage. The guinea-hen is an African bird. To this group belongs the curious mound-bird (*Megapodius*), of Australia and New Guinea. It heaps up a large mass of

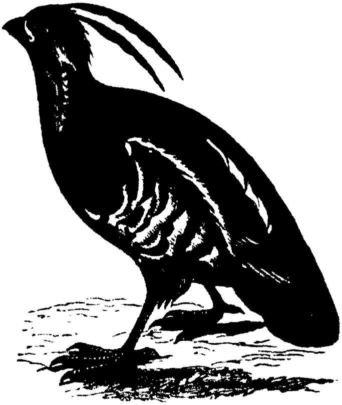

Fig. 471.—Plumed Partridge.—From Coues' Key.

rubbish, forming a hot-bed, in which its eggs are left to hatch. The megapods, together with the American guans and curassows (*Cracidæ*), form a sort of passage from the gallinaceous to the columbine birds. One of the most puzzling forms for the systematic ornithologist to deal with is the hoasin of Guiana (*Opisthocomus cristatus* Illiger). In this bird the keel of the breast-bone is cut away in front, the wish-bone unites with the coracoid bones, and also with the manubrium of the breast-bone, a thing of rare occurrence (Coues).

In the tinamous of Central and South America the tail-feathers are, in some cases, entirely wanting, and the breast-bone and skull-bones have some anomalous features. Most all gallinaceous birds have plump bodies, with short beaks and small rounded wings, not being good fliers. In some of their cranial characters they are so peculiar that Huxley makes them one of his primary divisions of *Carinatæ*.

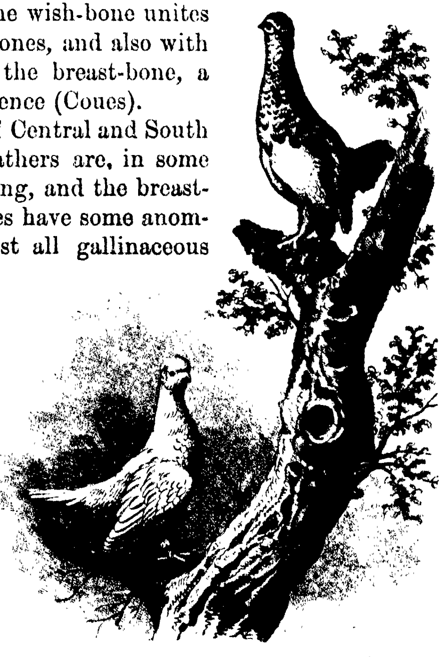

Fig. 472.—White-tailed Ptarmigan (*Lagopus leucurus*), in (upper figure) summer and (lower figure) winter plumage.—From Hayden's Survey.

We now come to birds of a higher type, in which the knee and part of the thigh are free from the body, the leg being usually feathered down to the tibio-tarsal joint; the toes are usually on the same level, being fitted for grasping or perching.

The doves are rapid fliers, but a notable exception is seen in their extinct ally the Dodo (*Didus ineptus* Linn.) of Mauritius, which became extinct on the island of Mauritius in the seventeenth century, while the solitaire, *Didus* (*Pe-*

zophaps) *solitarius* Schlegel, inhabited the island of Rodriguez, having been exterminated about the same date (1681). These were clumsy, defenceless birds, incapable of flight, and were destroyed by the domestic animals which accompanied the Portuguese voyagers to the Mascarene Islands. The doves and their allies now commonly form a group, called *Columbæ.*

The birds of prey (*Raptores*), comprising the vultures, buzzards, falcons, hawks, eagles, and nocturnal owls, have a hooked and *cered* beak—*i.e.*, with a waxy, dense membrane situated at the base of the upper mandible. The claws are large and sharp. The raptorial birds live either on birds and mammals, or fish, reptiles, batrachians, and insects. Of the vultures, the most notable for size is the condor of the Andes (*Sarcorhampus gryphus*), which has great powers of flight, its wings expanding nearly three metres (nine feet).

The carrion crow and turkey buzzard (*Cathartes atratus* and *C. aura* Illig.) are useful as scavengers, especially the former, which is partly domesticated in southern cities and towns ; they nest on the ground or in stumps, and are more or less social. The bald-headed eagle (*Haliaëtus leucocephalus*) is dark-brown when young, and before shedding its youthful plumage is larger than the white-headed adult. It nests on inaccessible rocky points ; is the sworn enemy of the fish-hawk, and, like it, fond of fish, often wresting its living food from the talons of the hawk. This species is the emblem of our country. The osprey or fish-hawk (*Pandion haliaëtus*) is two-thirds of a metre long, nests in tall trees, and is migratory. Among the hawks, the most notable are the falcons or hunting hawks, used during the Middle Ages in hunting the hare, etc.; in nature they chase their prey and kill it immediately, devouring it, and rejecting the bones and hair of the partly digested food in a ball from the mouth.

The owl is a bird of the night ; its flight is noiseless, owing to its soft plumage, the feathers having no after-shaft. It has large eyes and a hooked bill, giving the bird of Minerva an air of consummate wisdom. Owls capture living mice and other small nocturnal animals, ejecting from the mouth a ball of the indigestible portions of their meal. The little burrowing owl of the western plains (*Speotyto cunicularia, var. hypogæa*) consorts with the prairie dogs and rattlesnakes, nesting in the holes when deserted. Their rusty, dull hues assimilate them with the color of the soil they inhabit. Our largest owl is the great gray owl (*Syrnium cinereum*) ; it is nearly ¾ metre (2½ feet) in length, and

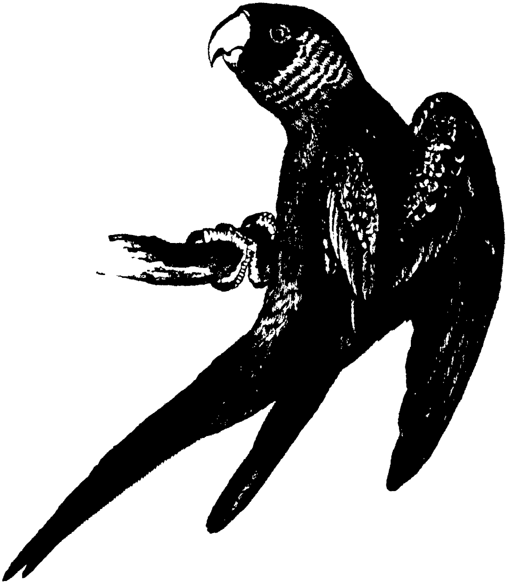

Fig. 473.—Carolina Parroquet.—From C

is an inhabitant of Arctic America. A visitor in winter from the Arctic regions is the snowy owl (*Nyctea nivea*), which is nearly ⅗ m., or two feet long. The great horned owl (*Bubo Virginianus*) is about the same size as the snowy owl, but has two conspicuous ear-tufts, adding to its height and its general impressiveness as a bird of more than ordinary sagacity.

Of more intelligence and gifted with the power of speech are the parrots (*Psittaci*). The tongue is large, soft, and remarkably mobile, as the muscles at the base are more distinctly developed than in other birds, and the lower larynx is complicated with three pairs of muscles; hence these birds are wonderful mimickers of the human voice, imitating the laughter or crying of babies, and repeating brief sentences, while some sing. In proportion to their capacity for talking, parrots command a very high market price. Their toes are in pairs, the bill is cered and very stout, adapted for cracking hard nuts. The wish-bone is sometimes rudimentary, and the sternum entire, not notched. Parrots are monogamous, like the hawks, and nest in rocks or hollow trees. Our only parrot is the Carolina parroquet (*Conurus Carolinensis* Kuhl, Fig. 473), which is common in Florida. It formerly extended to the Great Lakes and to New York, but is nearly exterminated. About three hundred and fifty species are scattered through tropical countries, Australia and South America being especially favored by these gorgeous birds. The ground parrot of New Zealand does not fly, all the others being good fliers.

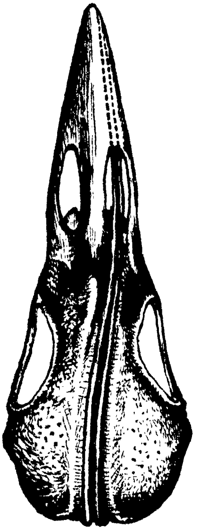

Fig 474.—Skull of *Gecinus viridis* L., showing the asymmetrical position of the horns (*cornua linguæ*) and their extension through the right nasal opening to the end of the

The *Picariæ*, a somewhat miscellaneous group of birds, comprising the woodpeckers, the cuckoos, and allies, the swifts and humming-birds, connect the preceding groups with the Passerine or singing birds. From the latter the *Picariæ* commonly differ in the form of the sternum, in the less developed vocal apparatus, there being no more than three pairs of separate muscles, so that the birds are not musical; as well as in the nature of the toes and wing and tail feathers.

The woodpeckers usually have pointed, stiff tail-feathers, and the bill is straight and strong. The tongue is long, flat, horny, and barbed at the end, and can be usually darted out with great force, so that the bird can make holes in the bark of trees and draw out the larvæ of insects boring under the bark ; in this way these birds render us signal service. The tongue, as in all vertebrates, is supported by the hyoid apparatus, especially by two cartilaginous appendages to the hyoid bone, called "the horns." These in the woodpeckers, when fully developed, are curved into wide arches, each horn making a loop down the neck, and thence bending upward, sliding around the skull, and even down on the forehead. Through a peculiar muscular arrangement of the sheaths in which the horns slide, they can be retracted down on the occiput, and work as springs on the base of the tongue, forcing it out with great velocity. Lindahl has noticed in some European woodpeckers an asymmetric arrangement of the horns as indicated in Fig. 474.

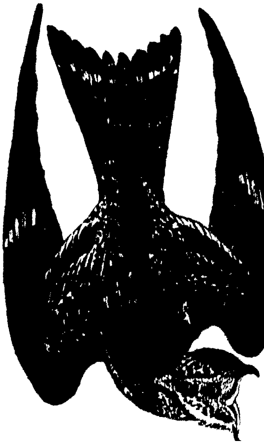

Fig. 475. — Nighthawk. — From Coues' Key.

The second group, the *Cuculi*. comprise the hoopoes, horn-bills, kingfishers, toucans, and cuckoos. These are succeeded by the *Cypseli*, embracing the humming-birds, goatsuckers, swifts, nighthawk (*Chordeiles Virginianus*, Fig. 475), and whip-poorwill, which have long pointed wings, great powers of flight, small weak feet, and, in the humming-birds, long slender bills. The latter are peculiar to America, being chiefly confined to South and Central America, only one species (*Trochilus colubris* Linn.) extending into the Eastern United States, though a dozen or more species occur in the Western United States, and very many in Mexico.

The highest group of birds, those which sing, are the *Passeres* or perchers. In these birds the feet are adapted for grasping, one toe projecting backward, while the bill is horny, usually sharp—conical, according to Coues. Various as are the shape of the wings, they agree in having the great row of coverts not longer than half the secondaries; the primaries either nine or ten in number, and the secondaries more than six. The tail, extremely variable in shape, has twelve rectrices (with certain anomalous exceptions). There is but one common carotid artery, and the sternum is very uniform in shape. Their high physical irritability is coordinate with the rapidity of their respiration and circulation; they consume the most oxygen and live the fastest of all birds (Coues).

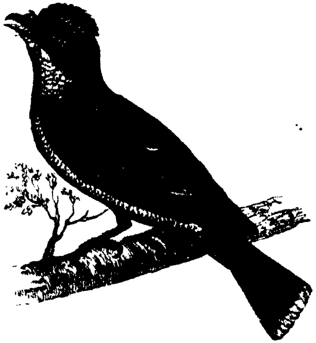

Fig. 476.—Kingbird.—From Coues' Key.

There are two groups of Passerine birds, differing in the structure of the lower larynx; in the first (*Clamatores*) the vocal organs are more or less rudimentary, the species not being singers, while in the second and higher division (*Oscines*) the lower larynx is so developed that most of the species excel as singers. In the singing birds the vocal apparatus (*syrinx*), or lower larynx, is situated next to the lungs at the end of the windpipe, with a muscular apparatus formed of five or six pairs of muscles, whose action varies the tension of the vocal cords and narrows or widens the glottides, which are elastic folds of the mucous membrane. A fold of the tympanal membrane of the syrinx, called the *membrana semilunaris*, projects inward.

Representatives of the *Clamatores* are the Acadian flycatcher, the wood pewee, the pewee or phœbe-bird, and the kingbird (Fig. 476). The last, sometimes called the bee-martin, Coues tells us, destroys a thousand noxious insects for every bee it eats. The lyre-bird (Fig. 477) is also a member of this group.

This bird, with tail feathers so strikingly developed (Fig. 477), is so peculiar among higher Passeres that it has been proposed to separate it, with certain probable allies, from all the rest.

The Oscines are represented by a host of species. These birds stand at the head of their class; and as they are mostly of small size, it may be said of them that they excel in quality, not quantity; most of them sing, being highly wrought, exquisite winged gems. Among the most notable are the jays, including the magpie of the Rocky Mountains (Fig.

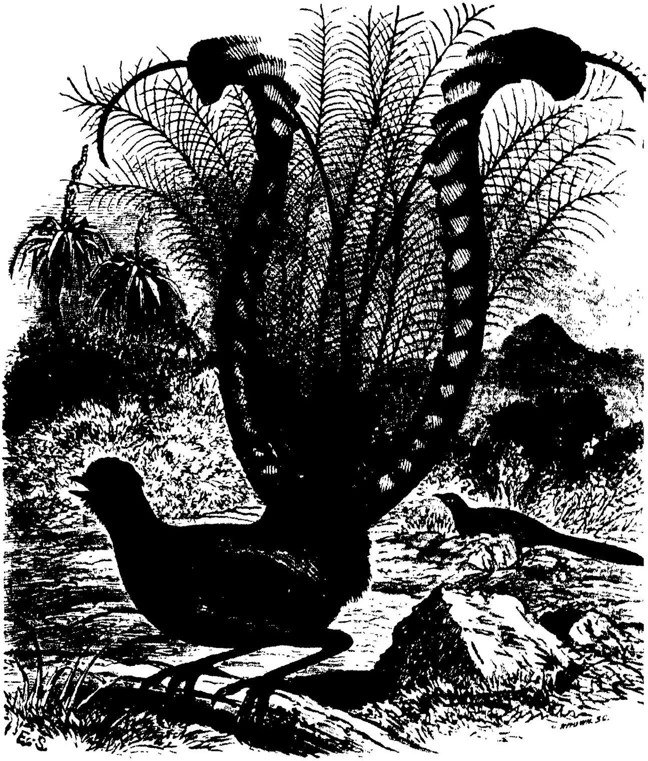

Fig. 477.—The Lyre-bird of Australia (*Menura superba*).

478), the crow, and blackbird, so useful a bird, notwithstanding its mischievous propensities; the oriole, whose hanging nest, brilliant colors, and lively song render it one of our most interesting birds; while the reed-bird of the

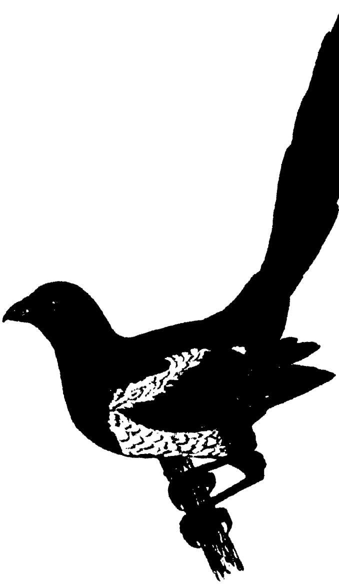

Fig. 478.—Magpie.—From Coues' Key.

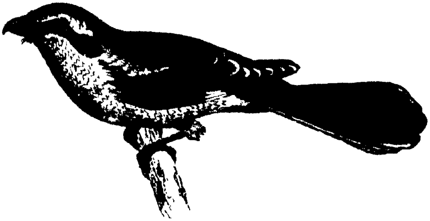

Fig. 479.—Butcher-bird.—From Coues' Key.

South or bobolink, as it is called in the North, wakes up the meadows with his lively notes. The finches with their conical beaks are succeeded, in the ascending series, by the English sparrow, a bird useful in the cities in destroying canker-worms, but a nuisance in the country. Our song-sparrow (*Melospiza fasciata*) is widely distributed, and everywhere commends itself by its pleasant notes. Quite opposed in its habits is the butcher-bird or shrike (Fig. 479), a quarrelsome, rapacious bird, which feeds on insects or small mammals, often impaling them on thorns or sharp twigs, and leaving them there. The group of vireos or greenlets (Fig. 480) are peculiar to America; their bills are hooked, with a notch at base; they are warblers. The wax-wing (*Ampelis cedrorum*, Fig. 481) is the type of an allied family. The swallows and martins are interesting from the change made in the nesting habits of the more common species which rear their young in artificial nests or in barns, or under the eaves of buildings.

Coues' Key.

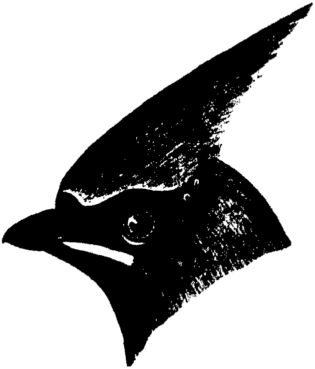

Fig. 481.—Carolina Coues' Key.

Another group characteristic of North America is the warblers, *Dendrœca* (*D. virens*, Fig. 482) being the representative genus. On the other hand, the larks are an Old World assemblage of birds, but few species occurring in this country, while the wrens (Fig. 483) are mostly restricted to America.

The smallest bird in the United States, except the humming-bird, is the gold-crested kinglet (*Regulus satrapa*

Lichtenstein), which is less than 9 cm. (3¾ inches) in length. Lastly come the bluebird, the melodious thrushes, and the

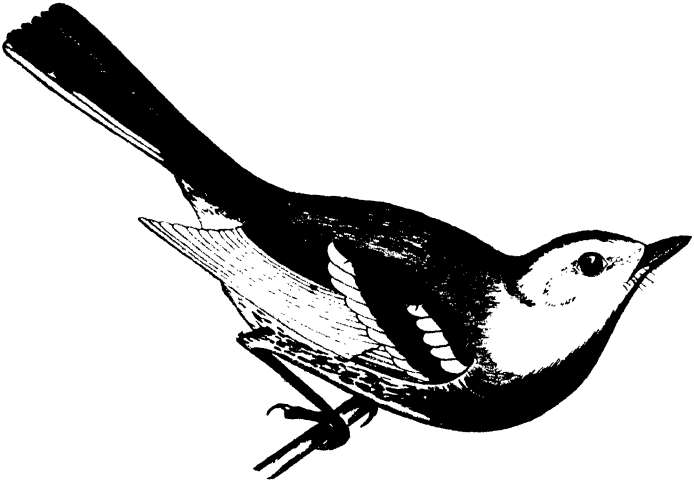

Fig. 482.—Black-throated Green Warbler.—From Coues' Key.

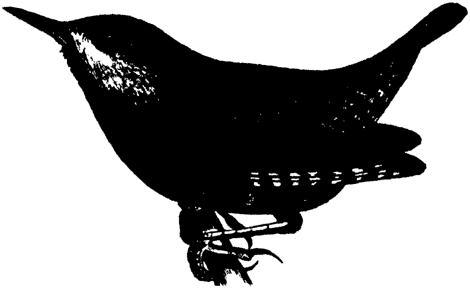

Fig. 483.—Winter Wren.—From Coues' Key.

mocking-bird, while at the head of the class in this country stands the robin (*Turdus migratorius* Linn.).

CLASS VI.—AVES.

Feathered Vertebrates; jaws encased in horny beaks in existing forms; the fore-limbs forming wings; warm-blooded; heart four-chambered; lungs with accessory air-sacs; the bones dense, hollow; oviparous; eggs very large, covered by a calcareous

Sub-class 1. *Saururæ.*—Tail as long as the body; head and fore limbs reptilian; with feathers, scales, and teeth. (Archæopteryx.[*])

Sub-class 2. *Odontornithes.*—Vertebræ biconcave, or as usual; jaws slender, with teeth implanted in sockets or in grooves; metacarpals co-ossified; sternum keeled or unkeeled; wings well developed. (Ichthyornis.)

Sub-class 3. *Ratitæ.*—Sternum smooth; wings rudimentary. (Struthio).

Sub-class 4. *Carinatæ.*—Sternum keeled; wings well developed. (Turdus.

Laboratory Work.—The student should prepare a skeleton of a hen or any other bird, and compare it, and especially the skull and limbs, with those of a reptile and a mammal. In dissecting a pigeon or fowl, attention should be given to those points previously indicated in which birds diverge from reptiles on the one hand and mammals on the other.

CLASS VII.—MAMMALIA (*Mammals*).

General Characters of Mammals.—In the mammals, which begin with the duck-bill, a creature in some respects reminding us of the birds, and end with man, we observe, as compared with birds, an increased complexity of structure; and in the nature of the work done by the different organs, we may see a constant tendency to a development of parts headward, so that the head becomes large in proportion to the body, the brain increases in size, and the fore-limbs finally become hands, ministering to the intellectual wants of the animal. Also, as we ascend the series, the body, from being horizontal, with limbs adapted for walking on all fours, becomes finally in the apes semi-erect, in man wholly so.

The greatest step in advance over the reptiles and birds is in the nature of the limbs, the structure of the head, the organs of special sense, together with the increased complexity of the teeth, and the size and complicated structure of the brain, particularly of the cerebrum and cerebellum.

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[*] Vogt believes that this is a bird-like reptile; a more perfectly preserved specimen having lately been found, showing that the head and fore part of the body were more reptilian than Owen supposed.

The more important (diagnostic) features of the mammals are the articulation of the lower jaw directly to the skull, the quadrate bone becoming one of the ear-bones (the malleus) ; there are two occipital condyles ; the teeth are differentiated into incisors, canines, premolars, and molars ; the body is covered with hair. The body-cavity is divided into two compartments (thorax and abdomen) by a large muscle, the diaphragm, so that the lungs are separated from the abdominal viscera. From the four-chambered heart the single aorta is reflected over the left bronchus ; the blood is warm, with non-nucleated corpuscles ; the circulation is complete, the blood being entirely received by the right auricle and transmitted by the right ventricle to the lungs for aëration, whence it is afterward returned by the left ventricle through the system. The brain is much larger than in birds, the cerebral hemispheres forming the bulk of the brain, and gradually, in different members of the ascending series, overarching and finally concealing from above the cerebellum. The cerebral hemispheres are more or less connected (and in nearly inverse ratio) by an anterior commissure and a superior transverse commissure (*corpus callosum*), the latter more or less roofing in the lateral ventricles (Gill). Mammals are viviparous, the embryo developing from a minute egg, and the young after birth are fed by the mother with milk secreted in the mammæ or mammary glands ; hence the name of the class, *Mammalia.*

Returning to the skeleton, which we may examine more in detail : the skull, as a brain-box, is much larger than in the reptiles and birds. The brain-cavity of *Coryphodon* and other extinct Tertiary mammals was exceedingly small, scarcely larger in proportion than in reptiles, and there is a progressive increase in size of the cavity of the skull in the more specialized descendants of this early Tertiary type, as seen in that of the horse, when compared with its Eocene progenitors. There is also a decided increase in the brain-box of the monkey as compared with that of the lemur, and of apes as compared with monkeys, while in man the brain capacity is twice that of the highest apes.

The different regions of the vertebral column are better defined than in the birds and reptiles; this is seen in the cervical vertebræ, the number of which is usually seven. The exceptions to this rule are few, there being six in one sloth (*Cholœpus*), eight or nine in another sloth (*Bradypus*), and six in the American manatee. Behind the cervical is the dorsal region, consisting of from ten to twenty-four, usually thirteen, vertebræ, and the lumbar region, which is composed of from two to nine, usually six or seven, vertebræ, and is marked off by the absence of movable ribs. The shoulder-girdle is not solidly united to the dorsal vertebræ, but loosely attached by muscles and tendons. The pelvis —*i.e.*, that portion called the ilium—connects with a single, sometimes two, rarely three, vertebræ of the sacral region, and the union of these vertebræ with one or more caudal vertebræ forms an assemblage of consolidated vertebræ, called the *os sacrum*, which in the sloths, or Edentates, comprises eight or nine vertebræ. The number of caudal vertebræ in the monkeys may amount to thirty, in the long-tailed manis (Fig. 501) to forty, while in other mammals there may be less than this number, there being four retained by man and the larger apes, while in some bats there are only three.

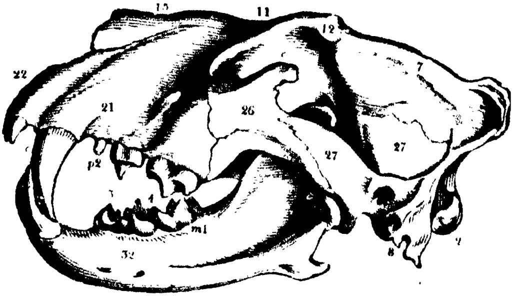

Fig. 484.—Skull of the Lion.—After Owen.

But it is in the limbs, and especially the feet, of mammals that the skeleton varies most, and always in accordance with the different habits of the creature. The limbs of mammals differ from those of the lower vertebrates in the fact stated by Gegenbaur, that the planes in which the angles of the limbs of either side are set are parallel to the vertical median plane of the body, thus giving greater independence to the limbs, which now become supports for the body, since they raise it from the ground. Beside this, the angles between the equivalent portions in each limb do not agree with each other, as in the reptiles, but point in an opposite direction in the case of the fore and hind limbs respectively (Gegenbaur). As we ascend in the mammalian series, the limbs, particularly the fore-limbs, are variously modified. The limbs of whales are paddle-like, though the bones of the limbs are homologous with those of other mammals. The feet of the seal are webbed, forming flippers; it cannot support itself on its limbs, but the fore-feet have considerable motion of the radius on the ulna. In the dog the fore-limbs have but little motion of the radius on the ulna, but the cats (*Felidæ*) have more of this rotary motion, enabling them to grasp with the fore-foot. This rotary motion of the fore-arm, involving the modification of the fore-foot into a hand, is seen in the thumbless monkeys (Fig. 485), and in those provided with a thumb, in the gorilla, and especially in man. The extreme of specialization of all four limbs is seen in the horse, which has but one digit, and walks on its single toe-nail. In the bat, the ulna and radius are fused together as one bone, and the last three fingers are greatly lengthened. The liberation of

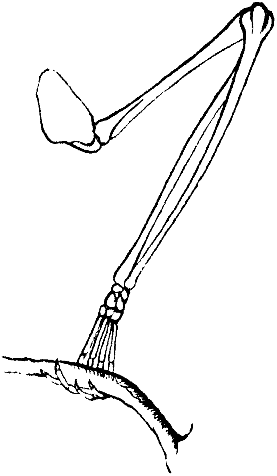

Fig. 485.—Arm of the Thumbless Monkey (*Ateles*).

the limb from the body becomes more marked as we approach man. In the seal, only the wrist protrudes from the skin, the limb of the otter slightly more; the horse's leg does not protrude beyond the elbow, that of the monkey projects two thirds of its length, while in man the limbs become wholly free from the trunk (Wyman).

The hairs originate in minute sacs which extend from the epidermis into the cutis; from the bottom of this inpushing of the epidermis grows up the shaft of the hair, which is surrounded at the base by the cellular wall of the hair-sac forming the root-sheaths. The spines of the porcupine, the scales of the Manis, of the armadillo, of the tail of the rat, are modified hairs, all developing in the same manner.

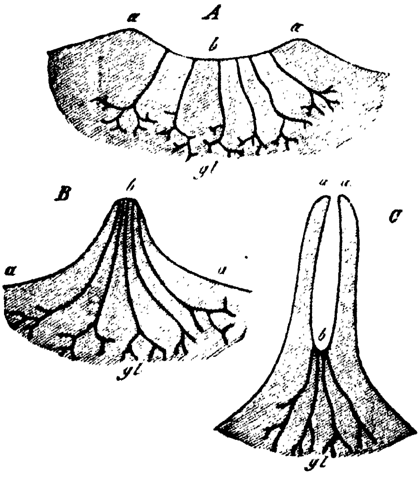

Fig. 486.—Diagram of the development of the nipple; vertical section. *a*, periphery of the glandular area (*b*); *gl*, glands. *A*, form of the gland in Echidna; *B*, its form in most mammals; *C*, its form in some ungulates, as the cow, mare, etc.—After Gegenbaur.

Many mammals, especially the ruminants, as the deer, ox, rhinoceros, etc., are armed with horns. There are two kinds, those with a bony core surrounded with a horny epidermal case as in the deer; while in others, as the antelopes, sheep, goats, and oxen, the horns are hollow; hence they are sometimes called *Cavicorns.* In most horned mammals, the horns are persistent; in the deer they are dropped annually; in the prong-horned antelope (Fig. 487) the horns are also shed annually.

The mammary glands are modifications of the tegumentary glands which are found in all vertebrates except fishes. In the duckbill and spiny ant-eater (*Echidna*), these glands retain their simple elementary nature. In all others nipples are developed (Fig. 486). They correspond in general to the number of young in a litter.

The dentition needs careful study in connection with the fossil remains of mammals, as the different orders are characterized in great part by the differences in the form and number of the teeth, which are intimately correlated with the structure of the digestive organs and the nature of the limbs; thus while vertebræ are useful in identifying or restoring fossil reptiles, the teeth are especially serviceable in classifying fossil mammals. Some existing forms are entirely toothless, as the duckbill, where the teeth are represented by horny plates, and the ant-eater (Fig. 488). While the sloths have no incisors, these are present and very large in the rodents, but the canines are absent (Fig. 489).

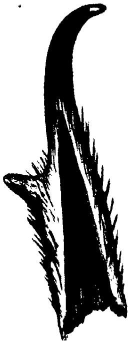

Fig. 487. — Hollow horn of the Prong horned Antelope.

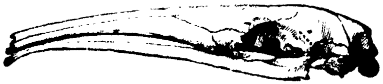

Fig. 488.—Skull of Ant-eater.—After Owen.

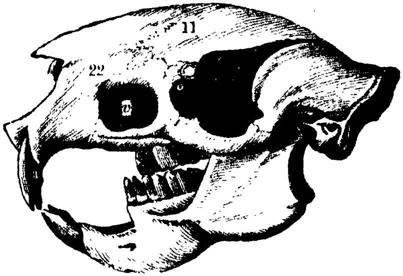

Fig. 489.—Skull of a Porcupine.—After Owen.

In the elephant the upper canines form the tusks, the corresponding teeth of the lower jaw being absent. In many teeth, as those of the deer (Fig. 490), the crown of the molars is quite convex, with crescent-shaped enamel areas. The canines are large and sabre-shaped in the cat family, while in the pigs, especially the babyroussa of Malaysia, the upper pair curve upward and backward to the forehead. The premolars and molars have two or three roots or fangs ; in none of the lower vertebrates do the teeth have more than one root.

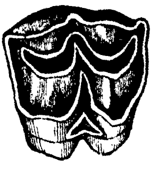

Fig. 490.—Crown of the tooth of a deer, showing the enamel crescents.—After Owen.

The organs of sense are much developed, especially the ear. The quadrate bone of the reptiles and birds, which is large, external, and suspends the lower jaw to the skull, now becomes minute, internal, and forms one of the internal bones (*malleus*) of the ear. The labyrinth of the ear, largest in fishes, is smallest in mammals. The cochlea

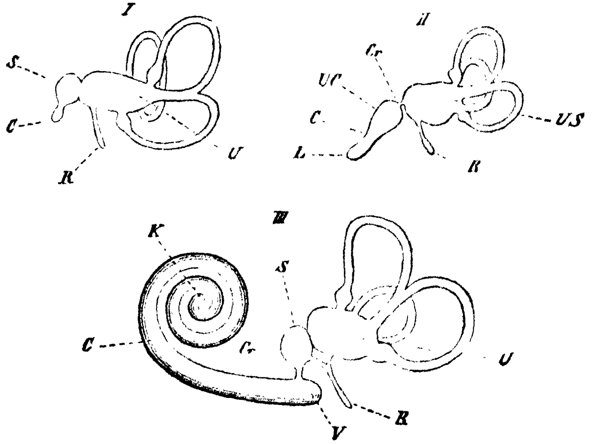

Fig. 491.—Diagram of the labyrinth of the ear in *I*, the fish, *II*, the bird, and *III*, a mammal. *U*, utriculus; *S*, sacculus; *US*, utriculus and sacculus; *Cr*, canalis reuniens ; *R*, recessus labyrinthi; *UC*, commencement of the cochlea, *C*, *L*, lagena; *K*, cæcal sac at the apex; *C*, cæcal sac of the vestibulum of the cochlear canal.—After Waldeyer, from Gegenbaur.

(Fig. 491, *C*) is greatly developed in the mammalia, while the external ear now appears. This is a prolongation of the edges of the first branchial cleft of the embryo. There is, however, no external ear in the Monotremes (duckbill). It is also absent in whales, the Sirenians or sea-cows, in most seals, and is very small in the eared seals (*Otaria*). The eye of mammals is not essentially different from that of the lower vertebrates.

The general anatomy of the soft parts of a mammal may be studied by dissecting a cat, with the aid of the following description and drawings prepared by Dr. C. S. Minot:

Fig. 492 illustrates the general anatomy of the cat; the skin and right half of the body-wall have been removed. The body-cavity is divided into an anterior and posterior division by a transverse arched partition, the diaphragm (*D*), composed of a thicker peripheral muscular portion and a thinner central tendinous part. Through the latter pass the great blood-vessels and the œsophagus. The anterior chamber is the thorax or pleural cavity, and contains the respiratory organs and heart. To show these, the right lung has been removed. The heart (*Ht*) was enclosed in the thin-walled pericardial sac, which has been cut away. The great systemic veins enter from behind—*i.e.*, dorsally; from below the *vena cava inferior,* passing up through the diaphragm and uniting opposite the heart with the large vein, *cava superior, V*, from above, the two emptying into the right auricle. The œsophagus (*Oe*) overlies the trachea (*Tr*). The aorta arises from the heart, and, curving upward and backward, runs to the *left* of both trachea and œsophagus, as indicated by the dotted lines, and continues its backward course just below the vena azygos, into the abdomen. The trachea gives off a bronchus to each lung (*Lu*). The lungs are sacculated elastic organs, with no main central cavity. They are separated dorsally by a thin median vertical membrane (*M*), the *mediastinum,* the equivalent of the mesentery in the abdomen. Lying on the side of the vertebral column can be seen part of one of the two chains of sympathetic nervous ganglia (*S*).

The abdominal cavity contains the principal reproductive, excretory, and digestive organs. The œsophagus terminates in the stomach almost immediately below the diaphragm. The stomach (*St*) occupies a transverse position, its larger (*cardiac*) end, which receives the œsophagus, lying on the left, the smaller (*pyloric*) end on the right. The pylorus has a sphincter muscle which can completely close the orifice. The stomach is followed by the long intestines (*In*), most of which have been removed, leaving a short piece in front. The posterior portion of the intestine is somewhat dilated, is called the *colon*, and passes into the wide terminal rectum (*Rec*). The whole abdominal portion of the intestinal canal is suspended from the median dorsal line by a thin membrane, the mesentery, which forms several folds, the most striking of which is the *omentum* or grand epiploon (*Om.*). This fold, when *in situ*, hangs down from the stomach like an apron, covering over the intestines ventrally. Upon opening the walls of the abdomen, it is the first structure met with. It usually contains a great deal of fat. Its principal function is supposed to be to prevent the loss of heat. The omentum is present in all mammals, but is least developed in Cetaceans, being most prominent in Carnivora and ruminants. Connected with the intestine are two glands, the liver (*Li*) and pancreas. The liver is large and lies directly underneath the diaphragm. The elongated light-colored pancreas lies alongside the front end of the intestine (*In*), or so-called duodenum; in its microscopic structure it resembles the salivary glands. The spleen is closely connected with the stomach, and is of an elongated shape, as in the majority of the *Mammalia monodelphia.*

The kidneys (*Ki*) are large and oval, and lie on either side of the vertebral column; the aorta passes between them, giving off a renal branch to each gland. A delicate *ureter* (*Urt*) passes from each kidney obliquely across the rectum to the large flask-shaped bladder (*Bl*). A *urethra* (*Ur*) arises from the bladder posteriorly and opens in the female immediately below the anus, but in the male enters the penis.

The ovary (*Ov*) is small and is placed near the open end of the oviduct or *Fallopian tube*, which can be seen in the figure extending alongside the rectum above the bladder. The two oviducts (*Ovd*) unite posteriorly to form the uterus (*Ut*).

Fig. 492, II., is a median longitudinal section of the brain. The spinal cord passes into the *medulla oblongata* (*M*), over which lies the large *cerebellum* (*Cb*), and the small *corpora quadrigemina* (*Q*). In front is the large *cerebrum* (*C*) and the small olfactory lobe (*L*). Fig. 492, III., is a diagram of the eye (see explanation of the figure).

By carrying the dissection further, the student will be able to examine the tongue with its papillæ; the epiglottis at the back of the mouth in front of the trachea; the larynx, a peculiarly modified portion of the trachea in the neck, with two elastic bands stretched across its interior; the bands or vocal cords may be set in vibration by a blast of air from the lungs. The heart may also be dissected further to find the origin of the pulmonary vessels, and to make out the four divisions or chambers. (Minot.)

The eggs of mammals are exceedingly minute, partly owing to the small quantity of yolk in them; the eggs of the few which have been examined are about a quarter of a millimetre ($\frac{1}{125}$—$\frac{1}{100}$ inch) in diameter. In the duckbill the egg is large and with more yolk, like those of birds, being about five millimetres in diameter. Mammals are divided into non-placentals and placentals, according as the embryos are surrounded or not with a *placenta* or "after-birth." This organ is a development of the allantois, serving as a means chiefly of nutrition, being filled with blood-vessels leading from the walls of the womb of the parent, and also acting as an organ of respiration, and to carry off the effete products by means of the maternal circulation.

Mammals may be born helpless and only partly developed, as in the Marsupials; or capable of locomotion and sucking milk, as in the calf or colt; or helpless for many months, as in human infants. The changes in the form of the body after birth are much less, on the whole, than in the birds.

The sexes differ externally in size and ornamentation.

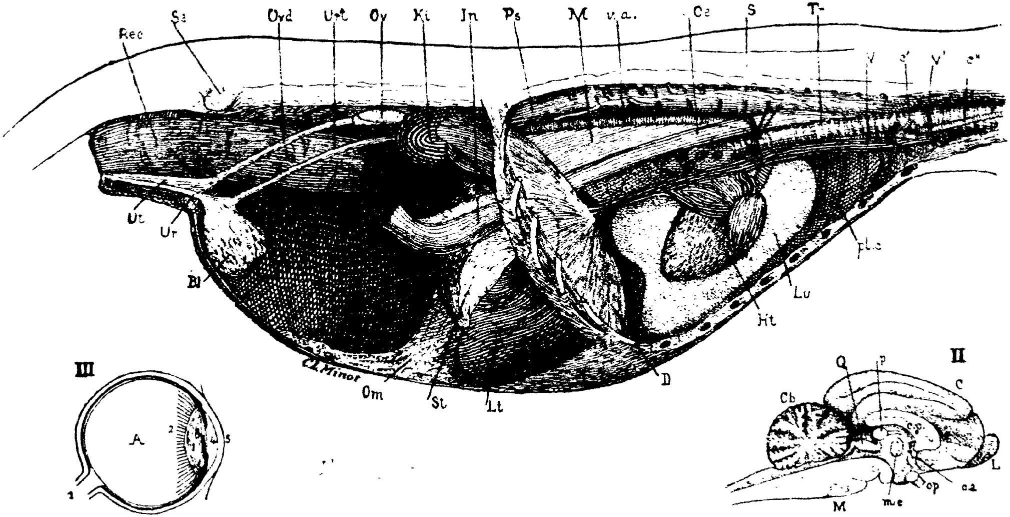

Fig. 492.—Anatomy of the Cat. *D*, diaphragm ; *Ht*. heart ; *Lu*. lung ; *pl c*, pleural cavity ; *V*, vena cava superior ; *V′*, vena jugularis ; *c′*, branch of the external ; *c″*, branch of the internal carotid ; *Tr*, trachea ; *S*, sympathetic ganglia ; *Oe*, œsophagus ; *v.a*, vena azygos ; *M*, mediastinum ; *Ps*, psoas muscle ; *In*, intestine ; *Ki*, kidney ; *Ov*, ovary ; *Ut*, ureter ; *Ovd*, oviduct ; *Sa*, sacrum ; *Rec*, rectum ; *Ut*, uterus ; *Ur*, urethra ; *Bl*, bladder ; *Om*, omentum ; *St*. stomach ; *Li*, liver.

Fig. 492, II.—Median longitudinal section of the brain. *M*, medulla oblongata ; *Cb*, cerebellum ; *Q*, corpora quadrigemina ; *p*, pineal gland ; *C*, cerebrum or hemisphere ; *L*, olfactory lobe ; *c.a*, anterior commissure ; *op*, optic nerve ; *m.c*, middle commissure ; *c.c*, corpus callosum.

Fig. 492, III.—Median vertical section of the eye, diagrammatic. 1, optic nerve ; *A*, posterior chamber, containing the vitreous humor ; 2, corpus ciliare ; 3, lens, partly covered in front by the pigmented iris ; 4, anterior chamber, containing the aqueous humor ; 5, cornea. The walls of the chamber *A* consist of three layers, represented by three lines, the outer the sclerotic the middle, the choroid ; the inner, the retina.—Drawn by C. S. Minot.

Darwin calls attention to the fact that in mammals the male wins the female rather by the law of battle than by the display of high colors and attractive ornaments. During the breeding season, desperate contests take place between the rival males; even the males of the timid hare will at such times fight until the weaker is killed; so moles, squirrels, horses, male seals and male sperm-whales, whose heads are larger than in the female, and beavers, will fight desperately. It is a rule that the males of such animals as are provided with tusks or horns always fight for the possession of the female. It is so with bulls, deer, elephants, boars, and rams; at the same time these are organs of defence by which the males protect their family, flock, or herd. On the other hand, in the female rhinoceros, some antelopes, the reindeer, as opposed to the other deer, some sheep and goats, etc., the horns are nearly as well developed as in the opposite sex. The modes of attack are various: the ram charges and butts with the base of his horns, the domestic bull gores and tosses any troublesome enemy, while the Italian buffalo "is said never to use his horns; he gives a tremendous blow with his convex forehead, and then tramples on his fallen enemy with his knees." Darwin also says that male quadrupeds with tusks use them in a variety of ways; thus the boar "strikes laterally and upward, the musk-deer with serious effect downward," while the walrus can strike either upward, downward, or sideways with equal dexterity.

The males are usually larger when there is any difference in size; this is seen in the eared seals, especially *Callorhinus ursinus*, in the ox, Indian buffalo, and the American bison, as well as the lion. The mane of the latter adds to its appearance of greater weight and bulk, and Darwin says that the lion's mane "forms a good defence against the one danger to which he is liable—namely, the attacks of rival lions." As regards distinctions in color, male ruminants are most liable to exhibit them. In the Derbyan eland the body is redder, the neck much blacker, and the white band separating these colors broader than in the females. In the Cape eland the male is slightly darker than the female. In the Indian black-buck the male is very dark, almost black, while the female is fawn-colored : male antelopes are blacker than the female. The Banteng bull is almost black, while the cow is of a bright dun. Among the lemurs the male of *Lemur macaco* is coal-black, while the female is reddish yellow. The sexes of monkeys differ much in coloration. Certain male seals, bats, rats, and squirrels have brighter colors than in the opposite sex. On the other hand, the female Rhesus monkey is adorned with a brilliant red naked ring around the tail ; this is wanting in the male, which, however, is larger, with larger canines, more bushy whiskers and eyebrows ; and Darwin states that in monkeys the males usually differ from the females in "the development of the beard, whiskers, and mane."

The vocal organs of mammals are, in general, constructed on the same type. The larynx is formed by a modification of the uppermost ring of the trachea, called the *cricoid* cartilage, to the anterior and dorsal edges of which two *arytenoid* cartilages are attached, while a V-shaped *thyroid* cartilage, open behind, is attached to its side. The *vocal cords*, which are modified folds of the mucous membrane lining the trachea, are stretched between the arytenoid and thyroid cartilages, the slit between them being called the *glottis*, which is covered by the *epiglottis*. Thus, in mammals the organs of voice are situated almost solely at the upper end of the trachea. In the whales the vocal chords are not developed. The male gorilla, which has an exceedingly loud voice, as well as the adult male orang and the gibbon, is provided with a laryngeal sac. In the howling monkey (*Mycetes*) of Brazil, the hyoid apparatus and larynx are remarkably modified, the body of the former being changed into a large bony drum or air-sac communicating with the larynx. The vocal organs are a third larger in the males than in the females. "The males begin the dreadful concert, in which the females, with their less powerful voices, sometimes join, and which is often continued during many hours" (Darwin). They apparently howl, as birds sing, for the simple pleasure of the thing. Apparently, the most musical mammal, man excepted, is a gibbon (*Hylobates agilis*), which can sing "a complete and correct octave of musical notes" (Martin *ex* Darwin). While quadrupeds use their voices as alarm calls, most of the sounds are produced by the males, especially during the breeding season.

Animals are mutually attracted or are individually protected from the attacks of other species by odors. The scent-bags or odoriferous glands secreting a fluid differing in consistency in different animals, are situated near the base of the tail, as in the skunk, polecat, musk-deer, civet-cat and allies, or they may be developed in the side of the face, as in the male elephant, as well as sheep and goats. The odor is either of musk or some form of it. The shrew-mice, by reason of their odoriferous glands, are disliked and consequently not hunted by birds. Universal deference is paid to the skunk; few dogs, and only those which are inexperienced or peculiarly gifted, attacking them. The males more usually emit a stronger odor than those of the opposite sex.

Some mammals have a summer and a winter pelage. The hare, at the beginning of winter, doffs its summer coat for a suit of white. The hybernation, or winter-sleep, is a remarkable feature in the life of quadrupeds living in the north temperate zone, such as the bear, dormouse, and bats. During this period the temperature of their body falls, respiration and circulation are lowered in the one case or nearly ceases in the other, and life is sustained by the absorption of fat, which accumulates on the under side of the neck in the so-called hybernation-glands.

There are about 3500 species of mammals described, of which 2100 are living; of these 310 inhabit America north of Mexico. Mammals live all over the earth's surface, but mostly in the tropical region, those of the arctic zones having been derived from the south since the end of the Tertiary period. The range in space of certain species is very great—for example, the cougar, panther, or puma ranges from British to South America (Chili). The mammalian fauna of the Tertiary deposits of the west was far more abundant than now, the remains of over five hundred species having been already discovered by Leidy, Cope, and Marsh in the few spots examined. The earlier (Eocene) mammals were generalized forms, combining in a remarkable degree characters more elaborated, and in great detail, in different orders of living mammals, especially the Ungulates. For example, from the Eocene *Coryphodon*, a generalized ungulate animal, have probably been derived the ruminants, the tapirs, hog, hippopotamus-like forms, the rhinoceros, and, finally, the horse. This inference is based on the fact that the bones and teeth of *Coryphodon* present characters which are no longer combined in any one species of mammals, but which are found worked out in detail in the members of the different orders referred to.

Moreover, the early Tertiary mammals had brains much smaller than in any existing forms, and with only one exception, without convolutions—showing that the development of the size of the brain and its convolutions, and consequently of the intellect, has kept pace with the successive stages in the specialization shown in existing forms, and which agree with the increasing complexity of the American Continent and the subdivision of the western part of the continent into distinct basins, with separate mountain systems and river-valleys. The result of all this apparent waste of generalized forms, and the survival of the few favored types now existing, has been the preservation of animals which have been domesticated by man, such as the dog, pig, horse, ox, camel, elephant, and of others useful as food or as intelligent servants ministering to his every-day wants.

The earliest mammals were small insectivorous or gnawing marsupials, none larger than a cat, and first appearing in Jurassic strata.

The Mammalia are divided into three sub-classes—viz., the *Ornithodelphia* (duckbill and *Echidna*), the *Didelphia* or marsupials, and the *Monodelphia*, comprising all the higher mammals.

Sub-class 1. *Ornithodelphia.*—The duckbill and spiny anteater (Fig. 493, *Echidna hystrix*) are the only representatives of the sub-class, of which there is but a single order, called *Monotremes*, and are distinguished by the following characters. The oviducts, *vasa deferentia* and ureters, open into the cloaca, as in birds. The sternum is provided with a peculiar T-shaped bone, and there are important features in the brain separating them from the members of the higher subclasses. There are several characters allying them to the

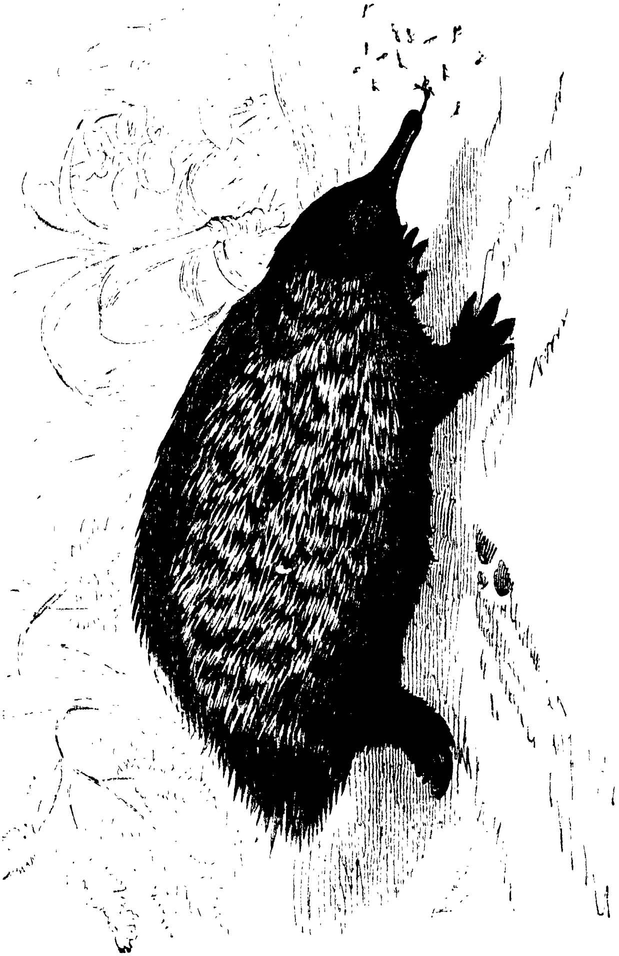

Fig. 493.—Spiny Ant-eater (*Echidna hystrix*).—From Brehm's Thierleben.

birds and reptiles, and besides those mentioned one of the most obvious is the long, toothless jaws (there are eight horny teeth in the duckbill), which are long and narrow in the *Echidna*, or broad and flat in the duckbill (*Ornithorhynchus paradoxus* Blumenbach), where it is covered by a leathery integument ; the external ear is wanting

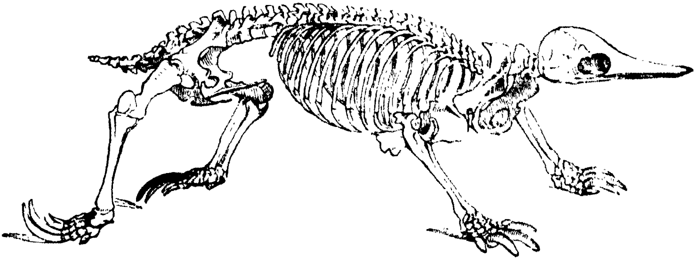

Fig. 494.—Skeleton of *Echidna hystrix*. From Brehm's Thierleben.

In the aquatic duckbill the feet are webbed, with claws of moderate size. It is covered with a soft fur, and is about half a metre (17-22 inches) long. Its habits are like those of a muskrat, frequenting rivers and pools in Australia and Van Dieman's Land, sleeping and breeding in holes extending from under the water up above its level into the banks, and with an outlet on shore. It lives on mollusks, worms, and water-insects. Young duckbills, five cm. long, have been found in their nests.

The spiny ant-eater (Figs. 493 and 494) is represented by three species, the *Echidna hystrix* Cuvier, of Australia, *E. Lawesii* Ramsay, from Port Moresby, New Guinea, also by a recently discovered form inhabiting the elevated portions of Northern New Guinea, and called by Gervais *Acanthoglossus Bruijnii*. In these singular animals the bill is long and slender, tooth-

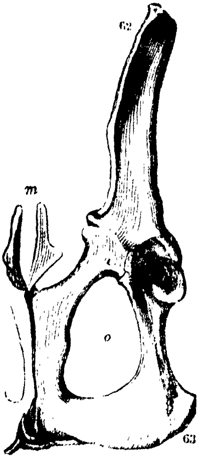

Fig. 495.—One half of pelvis of the Kangaroo; m marsupial bones.

less, while the palate is armed with rows of strong, sharp spines; the tongue is long and slender, like that of the ant-eater, while the body is armed with quills like those of a porcupine; the claws are very large and strong, adapted for tearing open ant-hills. All the species are from one third to one half of a metre (12–19 inches) in length.

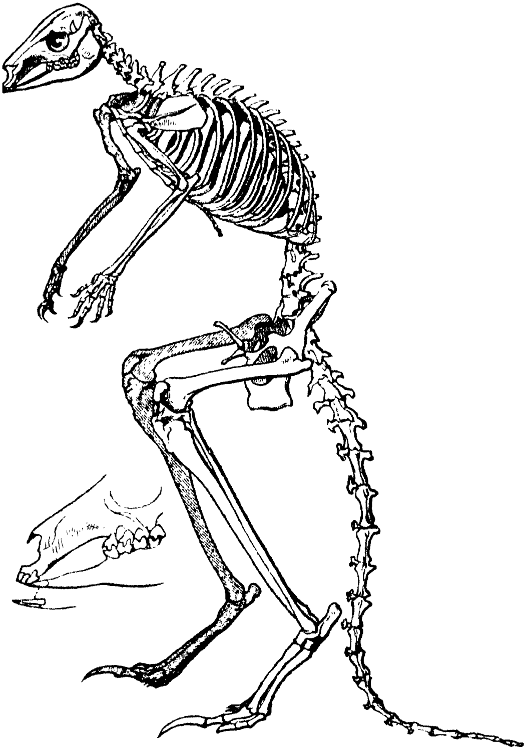

Fig. 496.—Skeleton of the Kangaroo.—From Brehm's Thierleben.

Sub-class 2. Marsupialia.—These are singular forms, represented by the opossum in this country, and the kangaroo, with a number of other forms, in Australia. They differ from all other mammals in having a pouch (marsupium) for the reception of the young immediately upon birth, where they are attached to the nipples at the bottom of the pouch. This large pouch (absent in some opossums and in the *Dasyuridæ*) is supported by two long slender bones attached to the front edge of the pelvis and projecting forward (Fig. 495 *m* and Fig. 497).

In *Thylacinus*, the Tasmanian wolf, these bones are cartilaginous. In the opossum, the kangaroo, and probably most marsupials, the young remains in the pouch attached to the nipple, which fills the mouth. "To this it remains attached for a considerable period, the milk being forced down its throat by the contraction of the cremaster muscle. The danger of suffocation is avoided by the elongated and conical form of the upper extremity of the larynx, which is embraced by the soft palate, as in the *Cetacea*, and thus respiration goes on freely, while the milk passes, on each side of the laryngeal cone, into the œsophagus" (Huxley). In the carnivorous forms the brain is low in structure, the olfactory lobes being very large, completely exposed, while the cerebral hemispheres are small and quite smooth.

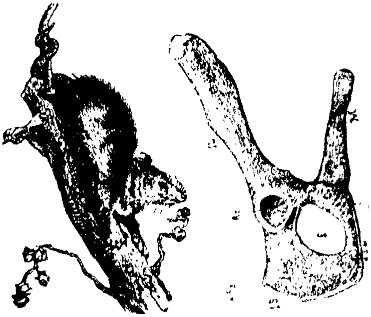
Fig. 497.—Opossum (from Tenney's Zoology) and side view of pelvis with the marsupial bone, *M.*

The dentition of marsupials is characteristic, none having three incisor teeth upon each side, above and below, and none but the wombat (*Phascolomys*), with an equal number of incisors in each jaw, there being usually more in the upper than in the under jaw.

The lowest marsupial is the Tasmanian wolf (*Thylacinus*), which is rather smaller than the wolf. The Tasmanian devil (*Dasyurus ursinus* Geoffroy, Fig. 383) is a vicious, troublesome creature, about the size of a badger. The opossums inhabit North and South America. They have a long tail and a plantigrade step—*i.e.*, they walk on the sole of the whole foot. The Virginian opossum (Fig. 497, *Didelphys Vir-*

giniana Shaw) lives chiefly in trees. Lawson says that "the female doubtless breeds her young at her teats, for I have seen them stick fast thereto when they have been no bigger than a small rasberry and seemingly inanimate. She has a paunch, or false belly, wherein she carries her young after they are from those teats, till they can shift for

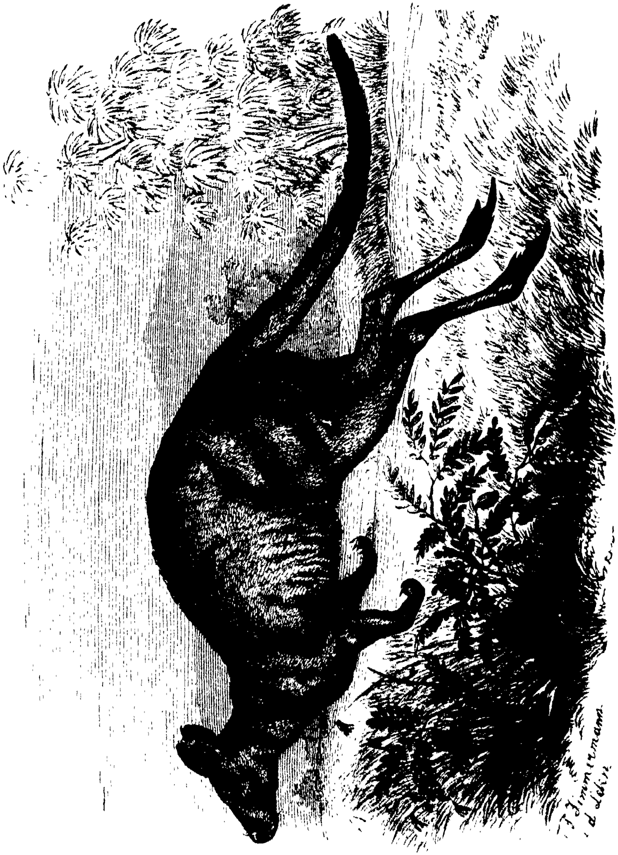

Fig. 498.—The Kangaroo (*Macropus*).—From Brehm's Thierleben.

themselves. Their food is roots, poultry, or wild fruits. They have no hair on their tails, but a sort of a scale or hard crust, as the beavers have. If a cat has nine lives, this creature surely has nineteen; for if you break every bone in their skin and mash their skull, leaving them for dead, you may come an hour after and they will be gone quite away, or perhaps you may meet them creeping away." ("Perfect Description of Virginia," 1649.)

There are squirrel-like flying marsupials (*Petaurus*), marsupial rats, marsupial bears, and marsupial ant-eaters (*Myrmecobius*), but the most characteristic Australian animals are the different kinds of kangaroo (*Macropus thetidis*, Fig. 498).

The largest species, *M. giganteus* Shaw, is 1·8 metres, or nearly six feet long. Kangaroos go in herds, and move by a succession of long leaps.

All marsupials are stupid, low in intelligence, and, in the insectivorous and carnivorous forms, of vicious temper. With the exception of the opossums, all are confined to Australia, New Zealand, and New Guinea.

Sub-class 3. *Monodelphia.*—While in the marsupials the termination of the oviduct is double, in the present group it is always single, whence the name *Monodelphia.* The members of the group are also called *placental Mammalia*, because the young at birth are of considerable size and nearly perfect in development, being nourished until born by a highly vascular mass or thick membrane (*placenta*) supplied with arteries and veins, developed originally from the *allantois*, which is a temporary embryonic membrane. The brain, as a rule, presents an advance over that of any of the preceding mammals, the *corpus callosum* being better developed, while the anterior commissures are all reduced. There are no marsupial bones, though in some *Carnivora* certain small cartilages appear to represent them.

There are twelve orders, as follows:

Order 1. *Bruta or Edentata.*—These creatures, represented by the sloths, ant-eaters, pangolins, and armadillos, stand next above the non-placentals or marsupials, as the brain is but little better developed, the hemispheres in some forms being nearly smooth, while, in point of their general structure and intelligence, they stand at the foot of the subclass. The teeth may be entirely undeveloped, as in the common ant-eater, but when developed they are not encased in enamel. In most Edentates the incisors are absent, but the lateral one may exist in the armadillo (*Dasypus*). The feet are formed for grasping or digging, and end in large straight or curved claws. They are either hairy or pro-

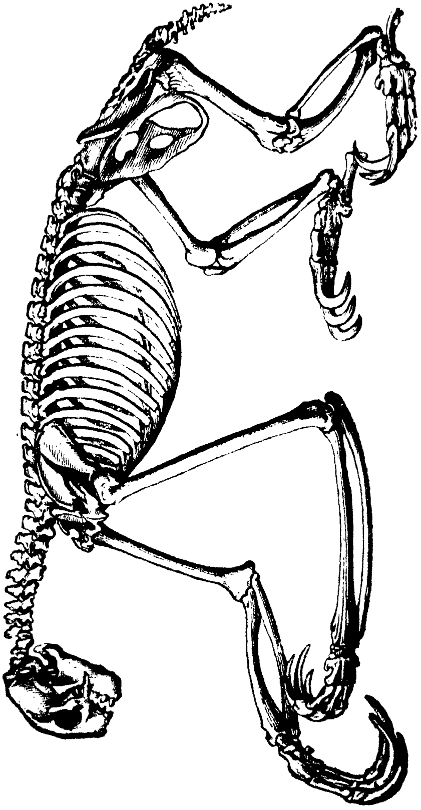

Fig. 499.—Skeleton of the Ai, or Three-toed Sloth.—After Owen

tected, as in the pangolins (Fig. 501) and armadillos (Fig. 502), with large thick scales. They feed on insects and decayed animal matter, or on leaves. They are of moderate size, though certain extinct forms were colossal in stature.

The leaf-eating forms, viz., the sloths, differ from the other *Bruta* in the very long and slender *limbs, the hinder* pair the shorter. There are five teeth above *and four below*, which become sharp with use, like chisels ; the stomach is said to be remarkably complex. In disposition these creatures are types of sluggishness ; they live in trees, being absolutely helpless on the ground, not being capable of walking on the bottom of the foot.

Waterton says that, in climbing, the ai (*Bradypus tridactylus*, Figs. 499 and 500) uses its legs alternately ; that its hair "is thick and coarse at the extremity and gradually tapers to the root, where it becomes fine as a spider's web. His fur has so much the hue of the moss which grows on the branches of the trees, that it is very difficult to make him out when he is at rest."

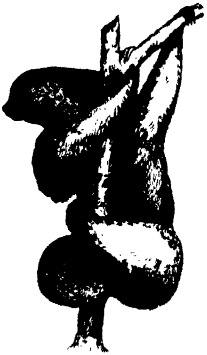

Fig 500.—Ai, or Three-toed Sloth, in its natural attitude.—After Wood, from Waterton.

None of the Edentates now occur in the United States, but formerly colossal, sloth-like forms, with some resemblance to the ant-eaters, ranged over the Southern and Middle States as far north as Pennsylvania, their bones occurring in caves. Such was the *Megatherium*, a gigantic, sloth-like creature, which extended from Pennsylvania to the pampas of South America, and whose skeleton is over five metres (18 feet) long. With it was associated the *Megalonyx*, first described by Thomas Jefferson ; it was as large as a bison, as was the *Mylodon*. These animals walked on the soles of the feet, could rise on their hind legs and partly support themselves by their thick tails, pulling down large trees and feeding upon the leaves and smaller branches.

In the ant-eaters the jaws are toothless, but very long, and the tongue is of great length and very extensile ; the submaxillary glands are very large, so that the viscid salivary fluid is very abundant. They burrow into ant-holes, thrusting the tongue among the ants, which stick in multitudes to the viscid, writhing rod, and are withdrawn into the mouth. The pyloric end of the stomach is gizzard-like. The anteaters (*Myrmecophaga*) inhabit South America.

The pangolins, or species of *Manis*, are mail-clad anteaters, the body and long tail being covered with large overlapping scales. When molested they roll up the body. In walking the hind feet rest on the soles, while the fore-feet are supported by the upper side of the long bent claws.

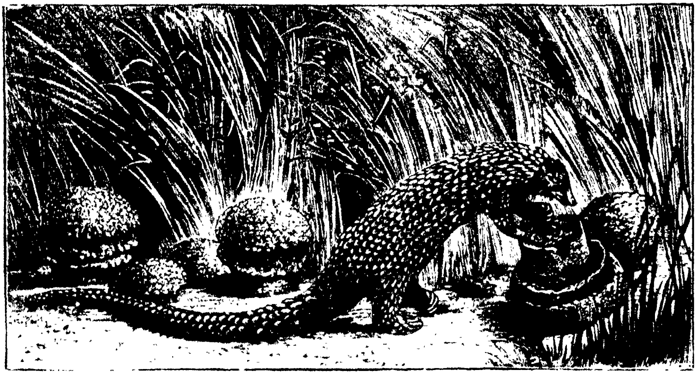

Fig. 501.—Pangolin (*Manis longicaudata*) robbing white ant-nests.—After Monteiro.

The long-tailed pangolin of the West Coast of Africa (Fig. 501) tears open with its long claws the nests of the white ants. It is nearly ¾ metre (28–30 inches) in length.

The armadillos (Fig. 502) are small mammals covered with a carapace, consisting of from three to thirteen transverse rows of movable scales; by rolling into a ball, these singular creatures become thoroughly protected from their enemies. *Dasypus novem-cinctus* Linn. is much like the Peba armadillo, and extends from South America to Texas. The strange extinct armadillo-like *Glyptodon* of South America, which was over two metres (8 feet) long, was covered by a heavy, solid coat-of-mail consisting of polygonal plates soldered together immovably.

The three following orders have by most authors been placed near the *Primates* (monkeys, etc.), but Owen, from

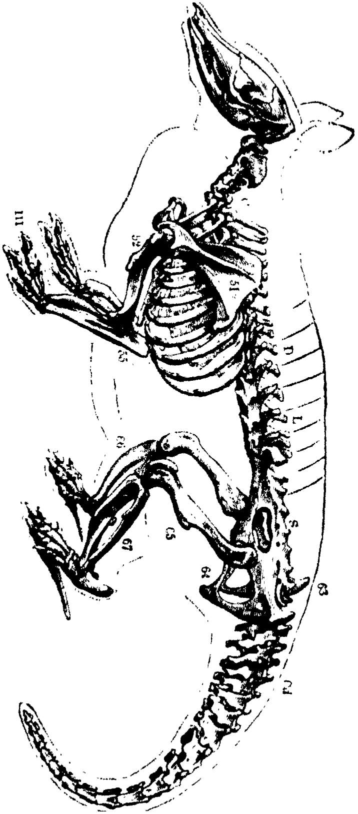

Fig. 502.—**Skeleton of Peba armadillo.** *D.* dorsal region, with the outline of the girdles of epidermal scales; *L.* lumbar region; *S.* sacrum; *Cd.* caudal or tail region; 65, femur or thigh-bone (the number is opposite the point of the third trochanter); 66, tibia; 67, fibula; 51, scapula; 52, humerus; 55, ulna.—After Owen

the characters afforded by the brain, has shown that they belong at or near the bottom of the scale. Gill has shown that not only by the brain, but by other characters correlated with the low development of the brain, the Rodents, Insectivora, and bats should be associated with the Edentates in Bonaparte's division (or, as Gill terms it, super-order) of *Ineducabilia* (which corresponds to Owen's sub-class *Lissencephala*). In these four orders, then, the cerebrum is small, smooth, with none or few convolutions; in front it does not cover the olfactory lobes, and behind leaves the cerebellum wholly or partly uncovered.

On the other hand, in the super-order *Educabilia*, comprising the following orders: *Cetacea*, *Sirenia*, *Proboscidia*, *Hyracoidea*, *Toxodontia*, *Ungulata*, *Feræ*, and *Primates*, the brain has a relatively large cerebrum, behind overlapping much, or all, of the cerebellum, and in front much, or all, of the olfactory lobes (Gill). The cerebrum is also convoluted; the convolutions increasing in number and complexity, until we reach the apes and man, and accompanied by increasing intelligence and capability for mental improvement. Other important characters are mentioned by Owen and by Gill in support of this arrangement.

In the smooth small cerebrum, as well as in other respects, the *Ineducabilia* are related, together with the marsupials and duckbill, to the birds and reptiles. In the cloaca, the convoluted trachea, the long, slender, beak-like, toothless jaws and the gizzard of the ant-eaters, the quills of the porcupine and hedge-hog, the proventriculus or crop of the dormouse and beaver, in the growing together of the three chief metatarsals of the jerboa, as in birds, in the keeled sternum and wings of the bats, there are points of resemblances to birds. Owen, whom we have quoted, also adds the aptitude of the bats, insectivores and certain rodents "to fall, like reptiles, into a state of torpidity, associated with a corresponding faculty of the heart to circulate carbonized or black blood."

However, there are points in which these orders are related to the lemurs and monkeys.

Order 2. Glires. (Rodentia.)—The rats, squirrels, porcupine, and beaver are common examples of this extensive group. They differ from other orders in the large incisors, the dental formula of which is normally $\frac{2}{2}$ ($\frac{4}{2}$ in *Leporidæ* and *Lagomyidæ*), and in the absence of canine teeth. The condyles of the lower jaw are longitudinal, not received in special glenoid sockets, but gliding freely backwards and forwards in longitudinal furrows. The feet are adapted for walking and climbing or burrowing, the claws being well developed. A peculiarity in the incisors is that they grow out as fast as they are worn down; this is due to the fact that the pulp is persistent; the enamel in front causes them to wear away behind so that they are chisel-shaped. The species are prolific, live mostly on vegetable food, and are of small size; the muskrat, beaver, and capybara being the largest members of the group. The flying squirrels (Fig. 503) take short flights by means of the expansion of the skin between the fore and hind legs. The Norway lemmings are noticeable for their remarkable migrations from the elevated

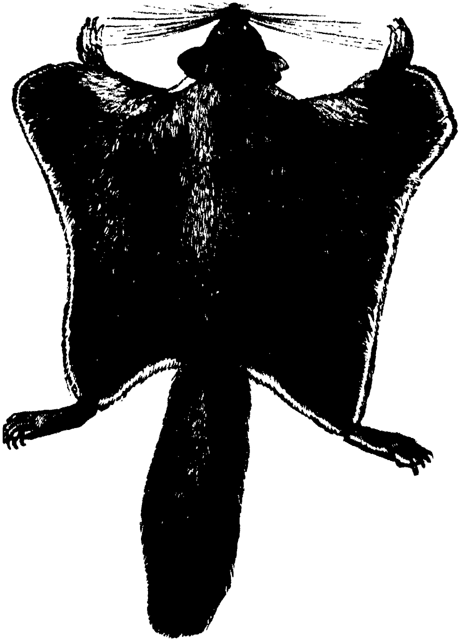

Fig. 503.—American Flying Squirrel (*Sciuropterus volucella*).

plateaus of Scandinavia down and into the sea; the object and origin of which are inexplicable, and are not indicative of much intelligence. From this and their nest-building habits, rodents are, as a rule, not unlike birds; and Owen, for these reasons, ascribes to them a low degree of intelligence. Granting that this is the case, an exception to this rule is seen in the social beavers, which evince a high, exceptional degree of intelligence. Beavers build a dam in a running stream so as to create an artificial pond as a refuge when attacked, as well as a subaquatic entrance to their lodges and to their burrows in the banks of the streams they inhabit. Beaver dams are built at first by a single pair or family, and are added to from year to year, and afterwards maintained for centuries by constant repairs. They are built of sticks and mud, usually curve up stream, with a sloping water-face. Beavers lay up stores of wood for winter use in the autumn; they can gnaw through trees eighteen inches in diameter; they work mostly at night. They often construct artificial canals for the transportation of the sticks of wood to their lodges. This, in the opinion of Mr. Morgan "is the highest act of intelligence performed by beavers." When ponds do not reach hard-wood trees or ground in which they can burrow for safety, they will build canals with dams, and so excavate them that they will hold the surface drainage. Morgan describes one canal about 161 metres (523 feet) long which "served to bring the occupants of the pond into easy connection, by water, with the trees that supplied them with food, as well as to relieve them from the tedious, and perhaps impossible, task of moving their cuttings five hundred feet over uneven ground, unassisted by any descent." Beavers, in swimming, use their tail as a scull, and the hind feet being webbed, its propelling power while swimming is very great. They carry small stones and earth with their paws, holding them under the throat, and walking on their hind feet. They use the tail in moving stones, working it under so as to "give it a throw forward." Beavers are very social, working together and storing up wood in common. "A beaver family consists of a male and female, and their offspring of the first and second years, or more properly, under two years old. The females bring forth their y from two to five at a time, in the month of May, and nurse them for a few weeks, after which the latter takes to bank." They attain their full growth at two years and six months, and live from twelve to fifteen years.*

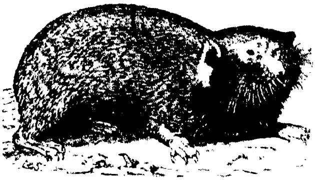

Fig. 504.—Sewellel or Showt'l. Much reduced.—From American Naturalist.

Allied to the beaver, but forming the type of a distinct family, is the singular sewellel or showt'l (*Haplodon rufus* Coues, Fig. 504) of the mountains of western Oregon and Washington Territory. It is nearly as large

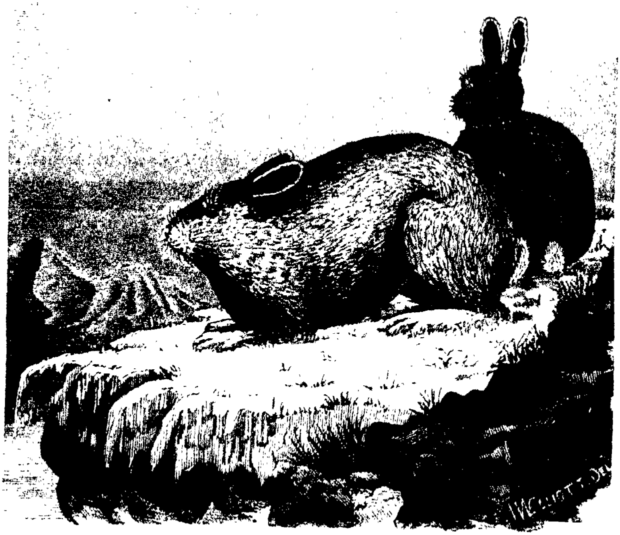

Fig. 505.—Alpine Hare of the Rocky Mountains.—After Hayden.

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* The American Beaver and his Works. By Lewis H. Morgan. 1868.

as a muskrat, is nocturnal in its habits and, therefore, rarely seen, and burrows in the earth, feeding on roots.

The lowest in intelligence are, perhaps, the hares, represented by the common varying hare (*Lepus Americanus* Erxleben, Fig. 505), of which an interesting variety, *L. Bairdii*, lives on the Alpine summits of the Rocky Mountains. The largest of all existing rodents is the Capybara of South America, which looks like a pig. This is succeeded by the porcupine, which either lives in trees or burrows in the earth, while the more intelligent, active forms are the beaver, muskrat, the European blind rat (*Spalax*, Fig. 506) the rats and mice, squirrels, and lastly the marmots. The domestic mouse and the two rats, the brown or Norway rat (*Mus decumanus* Pallas), the black rat (*Mus rattus* Linn.), and the common house mouse (*Mus musculus* Linn.), are cosmopolitan animals. The jumping mouse (Fig. 507) has remarkably long hind legs and short fore legs. Peculiar to the western plains is the prairie-dog, (*Cynomys ludovicianus*) which represents the marmots of the Old World ; it is semi-social and takes in perforce as boarders the owl and rattlesnake, which devour its young.

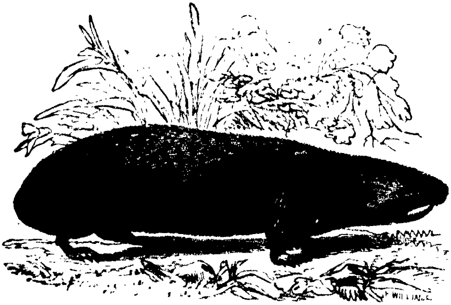

Fig. 506.—The Spalax or Blind Rat.—After Owen.

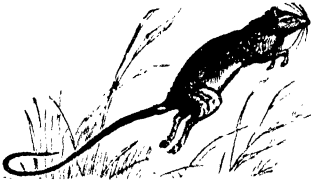

Fig. 507.—Jumping Mouse (*Zapus hudsonius*).—From Tenney's Zoology.

Order 3. *Insectivora.*—In the moles the incisors, the canines, and molars are well developed, and the molars have the crown surmounted by conical projections called *cusps.* The fore feet are plantigrade, with large claws, and the entire limb is short, thick, muscular, and fossorial, *i.e.*, adapted for burrowing in the soil (Fig. 508). The shrews comprise the smallest mammals. Nearly all are nocturnal, burrowing under the surface, and never seen by day; consequently, their eyes are small, and mostly hid under the fur; while the ears are small and concealed by the hair.

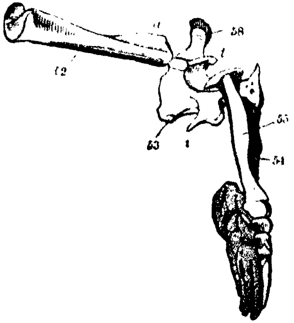

Fig. 508.—Bones of fore leg of Mole. 52, the cubital scapula; 53, humerus; 54, ulna; 55, radius.—After Owen.

The shrews are mouse-like, having feet of the normal form, and a long nose. In our common shrew (*Sorex platyrhinus* Wagner, Fig. 509), the nose is long, and the tail shorter than the head and body.

The genuine moles are the characteristic forms of the order; the most peculiar being the star-nosed mole, *Condylura cristata* Linn., which occurs from the Atlantic to the Pacific Ocean, while the common mole (Fig 510) is abundant in the Eastern United States.

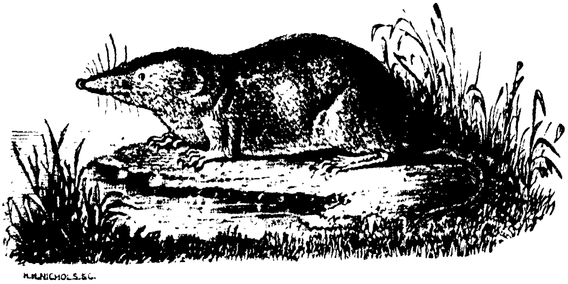
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Fig. 509.—Common Shrew.—After Coues.

A flying form with a superficial resemblance to the bat, and with the same habit of sleeping, head downward, holding on by its hind feet, is the *Galeopithecus* of the East Indies. This singular creature has been placed among the lemurs by some authors. *G. volans* Pallas inhabits Java, Sumatra, Borneo, and Siam.

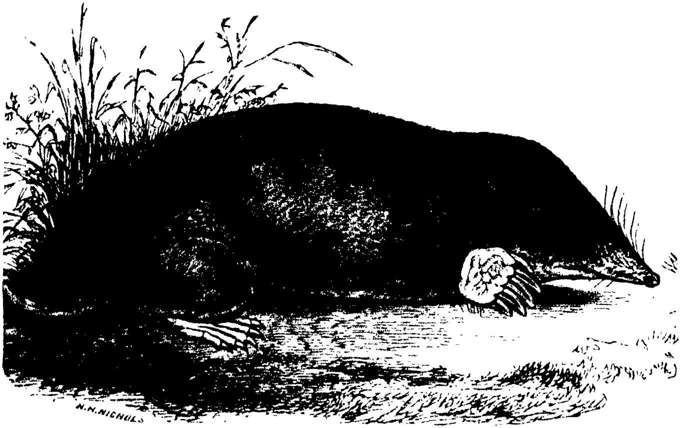

Fig. 510.—Common Mole (*Scalops aquaticus* Linn.).—After Coues.

Order 4. *Chiroptera.*—The bats form a well-circumscribed group of mammals, very distinct from any other, especially in the greatly modified fore-limbs, the radius and ulna being united, and the second to the fifth metacarpal bones and phalanges being very long and slender, supporting a thin, leathery membrane or skin, extending to the hind legs, and wholly or partly enclosing the tail; the hind toes being, however, free, as when at rest or in the vegetarians when feeding, bats hang head downwards, holding on by their claws. The sternum is slightly keeled for the attachment of the muscles of flight. The mammary glands are pectoral. In other respects, especially the dentition, the bats resemble the *Insectivora.* The form of the teeth differs from the ordinary insectivorous bats in those which live on fruit. The vegetable-eating or fruit-eating bats have a superficial resemblance to the flying lemurs; and because their mammæ are pectoral, have been placed next to the Primates.

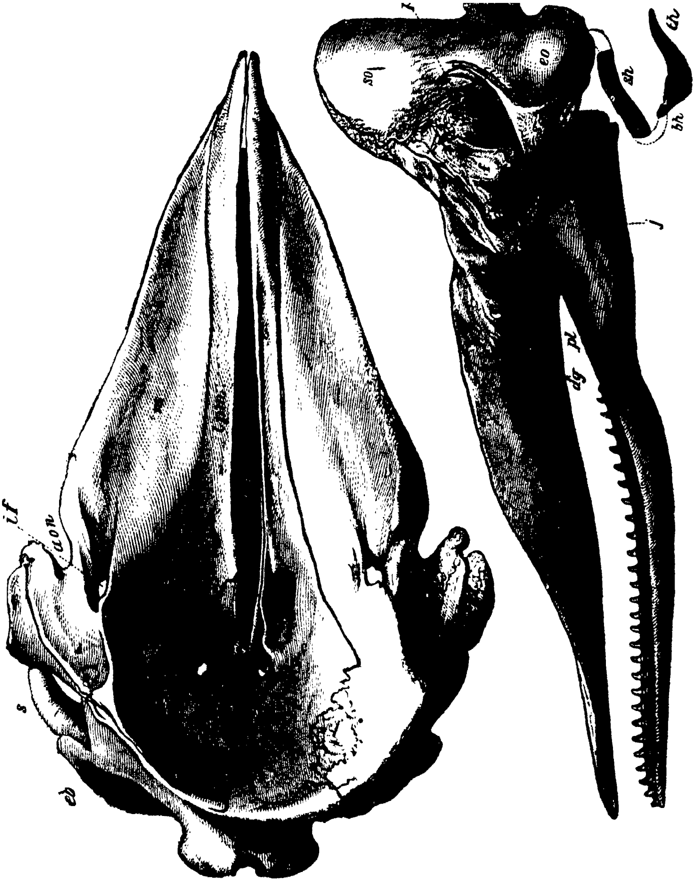

Fig. 512.—Skull of adult sperm whale seen from above and from the side. *bo*, basioccipital bone; *eo*, exoccipital; *so*, supraoccipital; *p*, parietal; *s*, squamosal; *f*, frontal; *pl*, palatine; *j*, jugal; *sh*, stylohyoid; *bh*, basihyoid; *th*, thyrohyoid.—After Flower.

the extremities of sleeping persons, who awaken to find their feet covered with blood.

The largest bats are the fruit bats or flying foxes (*Pteropus*) of the East Indies; one species of which expands one and a half metres (nearly five feet) from tip to tip of the wings. Our commonest species is the little brown bat, *Vespertilio subulatus* of Say; nearly as common is the red bat, *Atalapha noveboracensis* Coues.

Order 5. *Cete* (*Cetacea*).—We now come to the *Educabilia*, in which the brain is more highly developed, and begin with two very aberrant orders, the whales and Sirenians, in which the body is fish-like, though the tail is horizontal; the pelvis and hind limbs are wanting, either wholly, or minute rudiments may be present; and they are aquatic, occasionally leaping out of the water, but usually only showing the dorsal fin or nose when at the surface to breathe.

The whales and porpoises have a large, broad brain, with numerous and complicated deep convolutions.

In the skull (Figs. 512, 513) the aperture for the spinal cord (*foramen magnum*) is entirely posterior in situation and directed somewhat upward. The lower jaw is straight, with no ascending ramus, the narrow condyles being situated at the end of the jaw, at the point indicated by the angle of the ramus in other mammals. The teeth are conical, with a single root, but are sometimes wanting. There is no neck; the cervical vertebræ are sometimes confluent, forming a single mass. The

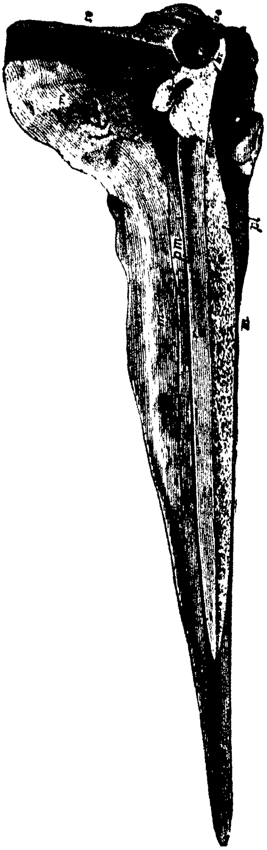

Fig. 513.—Skull of the whale, longitudinal section showing the relative size and form of the cranial cavity. *m*, maxilla; *pm*, premaxilla.—After Flower.

limbs form a pair of paddle-like appendages just behind and under the head, which are supported by short, flattened limb-bones, the carpals and phalanges often separated by cartilage; the second digit being composed of more than three phalanges. There are two mammæ situated near the anus. The external nostrils are either single or double, and are situated on the top of the head; they are modified to form the spiracles or "blow-holes;" certain folds of the skin prevent the water from entering the air-passages. The vapor blown from the holes does not consist of water, but of the mucus from the nostrils, and the moisture in the breath. The blow-holes vary in form in different kinds of whales. The "spout" of the sperm-whale issues in a single short stream from the extreme end of the snout, and curls over in front of the head; that of the fin-back whale forms a single column of vapor about ten feet high; the right, humpback and sulphur-bottom whales each "blow" in a double stream which is directed backward toward the tail.

Whales are rarely over fifty feet long; the sperm-whale has been known to reach a little over twenty-three metres (76 feet) in length, but Professor Flower questions whether the sperm-whale frequently, if ever, when measured in a straight line, exceeds a length of sixty feet. The largest of all whales, as of all existing animals, is the fin-back or rorqual (*Balænoptera boops*), which sometimes measures thirty-four metres in length. The smallest Cetacea are the porpoises.

In the *Mysticete* or whalebone whales, the teeth, present in the embryo, become reabsorbed into the gums before birth and are replaced by plates of whalebone (Fig. 514), three hundred of which may be present on each side of the mouth. The inner edges of these plates have projecting fibres, forming a rude strainer; these whales feed on small pelagic jelly-fish, molluscs and crustacea, by taking in a mouthful of water, and then pressing the tongue against the roof of the mouth, expelling the water through the openings between the plates, the fibres acting as a strainer. Three thousand five hundred pounds of whalebone have been obtained from a single bow-head or Greenland whale (*Balæna mysticetus*).

The cachelot or sperm-whale (Fig. 515) has an enormous head, and is without the power of smell. Above the nasal, frontal, and maxillary bones are cavities filled with a fatty fluid called *spermaceti*, used in the manufacture of candles, ointments, and cosmetics, such as cold cream. A large sperm-whale will yield 2500 kilograms of this substance. Another valuable substance is *ambergris*, a morbid product, the result of injury to the intestine by the beaks of cuttle-fishes, upon which animals the toothed whales largely prey. It is a kind of bezoar or gall-stone, fatty, aromatic, burning with a clear flame. It is composed of benzoic acid, united with chlorine, of a balsamic substance, and ambrain. It is used in making perfumes.

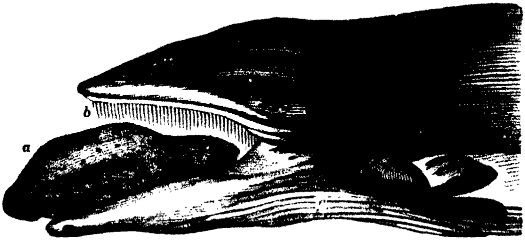

Fig. 514.—Head and tongue of finback whale, *Balænoptera* (the latter (*a*) swollen by the gases of decomposition); *b*, whalebone plates.

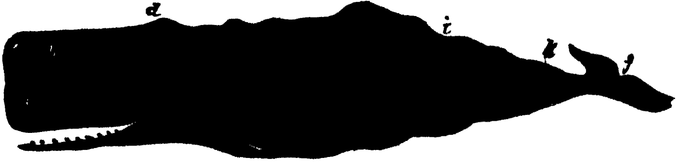

Fig. 515.—Outline of the cachelot, showing how the blubber is removed; *b*, the situation of the "case"; *c*, the junk; *d*, the bunch of the neck; *h*, the hump; *i*, the ridge; *k*, the small; *f*, the tail or flukes: between the oblique dotted lines are the spiral strips or blanket pieces.—After Beale, from Gill.

But the chief use of whales is the oil extracted from the fat enveloping the body, called blubber by whalers. The most valuable of the whales is the Greenland whale, as it contains the most oil, individuals having been known to yield nearly three hundred barrels.

The whale-fishery first sprang up in the twelfth century in the Bay of Biscay. In the New England colonies whales were pursued in boats from the shore. In 1854 the fishery culminated; since then it has decreased. It is principally carried on by Americans, New Bedford being now the leading port from which whalers are sent out to the Arctic regions and Behring's Straits, one hundred and ten vessels having been sent out in 1876 from this port.

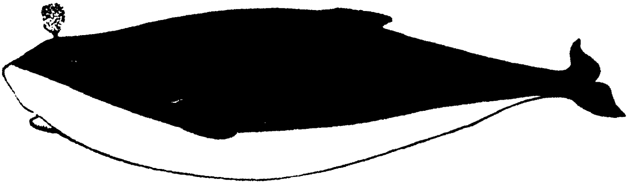

Fig. 516.—*Kogia Floweri.*—After Grayson, from Gill.

Closely allied to *Physeter macrocephalus* Lacépède, are the pigmy whales, represented on the Californian coast by *Kogia Floweri* Gill (Fig. 516), which is nearly three metres (nine feet) in length, with a conical head. In *Callignathus simus* Owen (Fig. 517) the skull is short and broad; it is found on the coast of Madras, India.

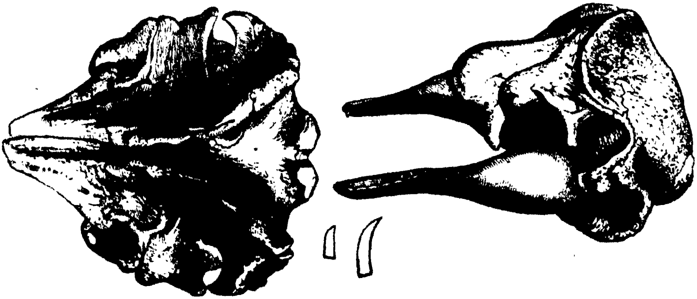

Fig. 517.—Skull of *Callignathus simus*, seen from the side and from below.—After Owen.

The narwhale (*Monodon monoceros* Linn.) is distinguished by the long, spirally-twisted, horn-like tusk of the male, formed of the left upper incisor, which becomes nearly three metres long, the female having no visible teeth; there being two rudimentary incisors which never appear through the gum. It ranges from Hudson's Straits to the Arctic seas, having formerly been seen along the coast of Labrador. To the family of dolphins and porpoises belong the white whale or *Delphinapterus leucas* Pallas, which ranges from the Gulf of St. Lawrence northward; the grampus (*Grampus griseus* Cuvier); the blackfish, of which there are two species, one *Globicephalus melas* Trail, ranging north of New York, and one *G. brachypterus* Cope, to the southward, and the porpoises, of which the most common on our coast is *Phocæna brachycium* Cope; the rarer is *P. lineata* Cope. On the coast of Labrador, as well as northward, occurs the thrasher whale or killer (*Orca gladiator* Gray) which has large teeth, and a high dorsal fin; it attacks whales, gouging out the flesh from their sides. Certain fossil whales were pigmies in size; while the *Zeuglodon* of the Alabama Eocene Tertiary beds, was an enormous serpent-like whale, which must have measured over seventy feet in length.

Order 6. Sirenia.— In the few species of sea-cows representing this order, the lower jaw is more as in other mammals, having well developed ascending rami and normal transverse condyles and coronoid processes. The teeth are well developed, both incisors and molars, the latter with flattened or ridged crowns, adapted for the trituration of vegetable food. A neck is indicated; the two nostrils are situated at the upper part of the snout, and the lips are beset with stiff bristles, while the mammæ are pectoral. The fore limbs are of moderate length, with five well-developed digits, but still fin-like and bent at the elbow. The brain is narrow compared with that of cetaceans, and the heart is deeply fissured between the ventricles. The manatees of America and the dugong of Australia and India (Fig. 518) live in the mouths of large rivers, feeding on seaweeds, aquatic plants, or the grass along the shore. The Florida manatee (*Manatus Americanus* Desmarest) grows to a length of from two to nearly three metres. It ranges from Florida to the Amazons, where it is called *Vacca marina;* it ascends the river as far as Pebas, Peru, and is killed and eaten, its flesh resembling beef.

Steller's manatee (*Rhytina Stelleri*) was in the last century found in abundance on the shores of Behring's Island on the coast of Kamtchatka; twenty-seven years afterwards (in 1768) it was totally exterminated by the sailors, and only a few imperfect bones exist at St. Petersburg. This is the largest Sirenian known: it was over six metres in length. It differed remarkably from the other forms, in having no teeth, but was provided with a very large, horny, palatine plate, and a corresponding one covering the enlarged point of union, or symphysis, of the lower jaws. In the Tertiary

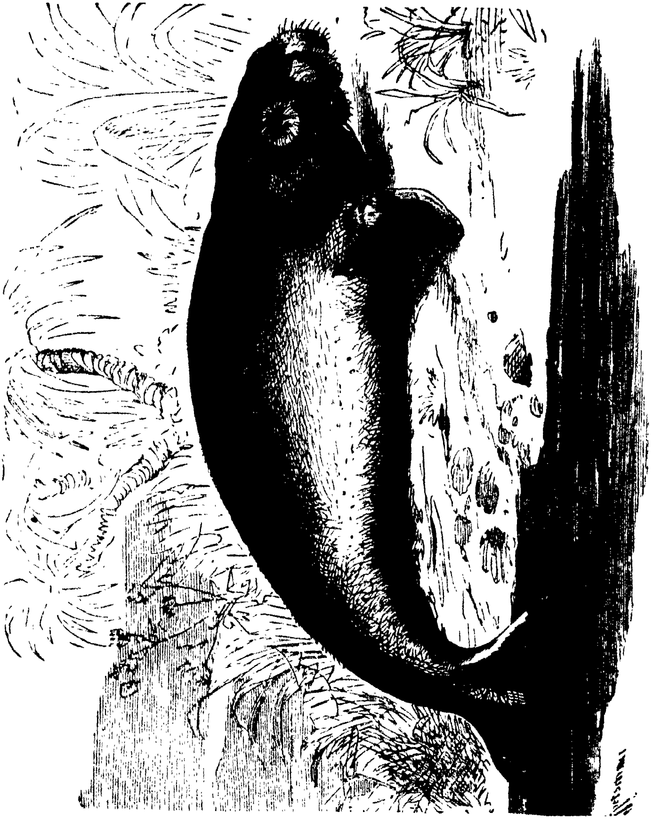

Fig. 518.—The Dugong.—From Brehm's Thierleben.

Period a fossil Sirenian (*Halitherium*) inhabited the shores of western Europe.

In the structure of the skull, their dentition and their herbivorous habits the Sirenians in a degree connect the Cetaceans with the Ungulates.

Order 7. Proboscidia.—Only two representatives of this group are now in existence, the Asiatic and African elephant, a number of other forms having become extinct. The group is well circumscribed, when we consider the living species, but in the early (Eocene) Tertiary Period there existed forms which indicate that the Proboscidians and Ungulates had a common origin. In the elephants the upper incisors are enormously developed, while there are none in the lower jaw. There are no canine teeth, while the few molars are large, transversely ridged. In the elephants the ridges are numerous, the spaces between them filled with cement. The young mastodon has cement on the upper surface of the tooth; the ridges afterwards become free and covered with enamel. A peculiarity in the elephant's skull is its large size, the brain cavity being very small in proportion to the bulk of the skull itself. To give lightness to what would be otherwise an insupportable weight, the cranial bones contain numerous large air-cells (Fig. 520). Another remarkable feature, from which the group takes its name, is the trunk or proboscis, a long, thick, fleshy, flexible snout, growing from the front edge of the nasal

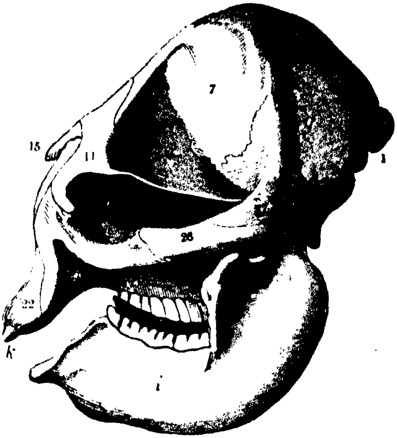

Fig. 519.—Skull of young elephant; 22, premaxillary bone containing the root of the tusk, *k*; 15, nasal bone; 7, parietal bone or temporal region; 26, molar, zygomatic arch; *i*, lower jaw; *c*, upper jaw; *m*, molar tooth; 21, maxilla; 11, frontal; *g*, squamosal.—After Owen.

bones (Fig. 520, *a*). The trunk ends in a finger-like, highly sensitive point, below which are situated the nostrils. The brain has a large cerebrum, with numerous convolutions, but more of the cerebellum is exposed than in any of the succeeding orders ; in this respect and in the large incisors the Proboscidians approach the *Rodentia*.

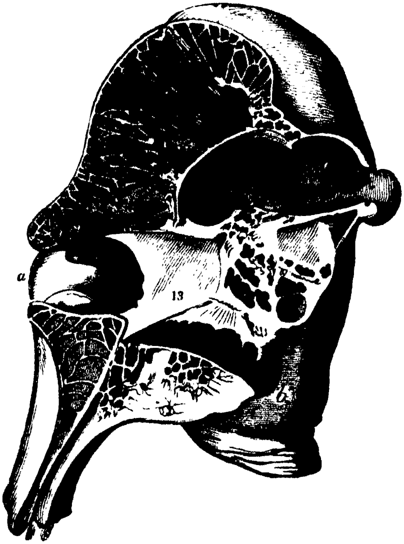

Fig. 520.—Section of an elephant's skull, showing the small size of the brain cavity as compared to the whole skull, and the numerous large air cells. *r*, posterior nostrils ; 13, cavity of the nose ; *a*, front opening of the bony nostrils, to the edge of which the trunk is attached.—After Owen.

In the nature of the limbs, especially from the fact that elephants walk on their toes, a relation to the Ungulates is indicated. They are five-toed, but the digits are represented externally only by the five broad, shallow hoofs, the foot being supported by thick, broad pads. The legs are almost wholly free from the body. The placenta is zonary and deciduate. The skin is naked in the existing elephants, but the extinct mammoth was covered sparsely with hairs. Elephants live in herds, browsing on the leaves of trees and herbs. They attain a height of from three to four metres (10–12 feet). The Asiatic elephant has a concave forehead and small ears, while the African species has a full, rounded forehead and large ears, with four hoofs on the fore feet and three on the hind feet, the Asiatic elephant having one more hoof on each foot. The fossil mammoth (*Elephas primigenius* Blumenbach), which was contemporaneous with early man, was not much larger than the existing species. Its tusks, however, were of great size, some being five metres long. It formerly ranged in herds over northern Europe and Asia, as well as America, bones occurring under swamps in the Northern and Middle United States. A carcass frozen in the ice, with the hair still on, was discovered near the mouth of the Lena River in Siberia. A pigmy, extinct Maltese elephant of the late Tertiary Period was only 1.7 metres in height.

The *Mastodon* was characterized by having incisors in both jaws of some of the species. The mastodon had molars with conical cusps, and was 3¾–4 metres (12–13 feet) in height. The mastodon (*Mastodon giganteum* Cuvier) was an earlier type than the elephant, and formerly inhabited the North American continent.

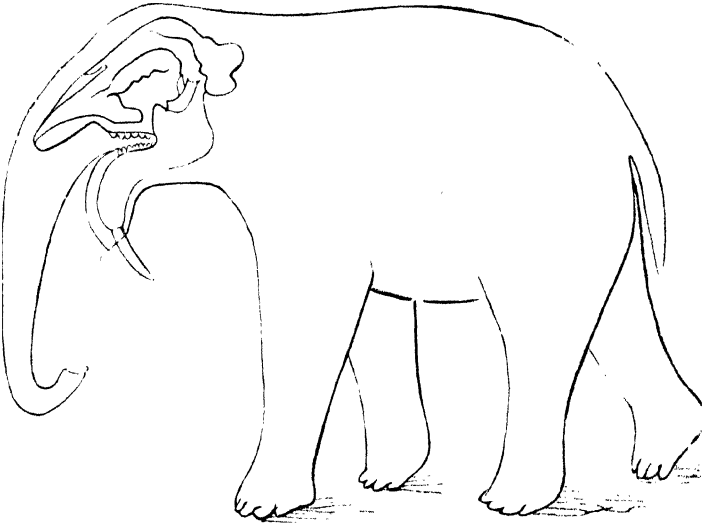

Fig. 521. Dinotherium.—From a restoration by Brandt.

In the *Dinotherium* of the Middle Tertiary (Fig. 521) there were only two incisors, and they grew out from the under jaw. It was elephantine in its form, according to Brandt.

Order 8. Hyracoidea.—With some affinities to the *Rodentia*, and a decided resemblance in some particulars to the rhinoceros among the Ungulates, the members of this small order are in general characterized by having long, curved incisors; and by feet provided with pads as in Rodents and *Carnivora*, the toes being encased in hoofs (four in front and three behind). The *Hyrax*, a little gregarious animal living in holes among rocks, of which there are two or three species known, one South African, and another in the Holy Land and Arabia, thought to be the coney referred to in the Bible, is the only genus.

Order 9. *Toxodontia.*—Of this group, of which no species are now living, the types are *Toxodon* and *Nesodon.* They are placed by many authors among the odd-toed Ungulates, not far from the tapirs. Their incisors were $\frac{6}{6}$ or $\frac{4}{6}$. *Toxodon* in its skull bore some resemblance to the Sirenians, and in the teeth were in certain respects like the Edentates. The species lived in South America during the early Tertiary Period.

Order 10. *Ungulata.*—The larger proportion of mammals belong to this interesting order, which comprises nearly all those species of mammals useful to man, such as the ox, camel, pig, deer, and horse. They are, in general, characterized by walking, so to speak, on their toes, each toe being at the end encased in a horny hoof; not more than four toes being completely developed on a foot. The teeth are usually well developed, with six incisors in each jaw, but these are often, especially in the upper jaw less in number or entirely absent, as in the sheep, deer, and ox. The collar-bone is absent. The brain still remains small compared with the bulk of the skull, and the intestinal canal is of unusual length compared with that of animals of the previous orders.

The Ungulates have been divided by Owen into two suborders, according to the odd number of toes (*Perissodactyla*) or even number (*Artiodactyla*). In the Perissodactyles there may be three toes on each foot, as in the rhinoceros, or one, as in the horse; while in the Artiodactyles there may be four toes (*Hippopotamus*), or two, as in the giraffe, or two functional and two rudimental, as in the ox and deer, *i. e.*, most Ruminants. The more generalized existing form of Ungulates is the tapir; the most specialized type is the horse, with its single toe on each limb. A large number of extinct Tertiary Ungulates in the Western States and Territories, and the Tertiary basins of Paris and London, more or less allied to the tapir, especially *Coryphodon*, *Anoplotherium*, *Palæotherium*, etc., were generalized or ancestral forms, from which the modern, more specialized types have probably been evolved, and a study of these fossil Ungulates shows that there was then (*i. e.*, in Eocene times) an essential unity of organization in all Ungulates, including the Ruminants; the breaking up of the Ungulate stem into special groups, along favored lines or paths of development, having resulted in a gradual improvement and elaboration of particular parts, which rendered them more fitted for their present life, and more intelligent in meeting and overcoming the emergencies their more complex surroundings subjected them to. Thus in the Eocene Ungulates, such as *Coryphodon*, the cerebrum was small, without convolutions, indicating a slight degree of intelligence compared with the modern Ungulates, while the gradual differentiation of the horse, with its single toe and hoof, from its tapir-like ancestors, is a marked example of the intelligent, beneficent selection of favored, useful types which has gone on from the earliest geological times.

All this specialization of type involved the destruction of great numbers of forms unfitted to withstand changes in their surroundings, or not sufficiently intelligent or wary to avoid the attacks of carnivorous forms, and thus the present number of Ungulates is much exceeded by the fossil forms.

Perissodactyles. The odd-toed Ungulates, on the whole, stand lower than the even-toed forms. They all have at least twenty-two dorsal and lumbar vertebræ, and a simple stomach, with a large, sacculated cœcum. The tapirs are the more elemental, generalized forms. Fossil tapirs occur in the older Tertiary beds of the West. The snout is almost proboscis-like, and the legs are moderately long, with four toes in front, three toes behind. The tapirs inhabit the tropics of the New World and Sumatra. They are succeeded by the rhinoceros, represented in this country by a number of extinct Tertiary allies, the living species being restricted to Africa and the East Indies. The skin is remarkably thick and dense, while these animals have either one or two long median horns growing from the skin of the nose. A rhinoceros contemporary with early European man formerly inhabited England, France, and Germany, and extended into Siberia.

A number of fossil forms lead up to the family comprising the horse, ass, zebra, and quagga, etc., in which there is a single toe, being the third on each limb. Their dention is—

$$I\frac{6}{6}, C\frac{1-1}{1-1}, P\frac{4-4}{4-4}, M\frac{3-3}{3-3}.$$

The genealogy or series of ancestral extinct Ungulates leading from tapir-like forms to the modern horse has been worked out partly by Huxley, and especially by Marsh, who has with Leidy discovered a large series of remains in the Tertiary beds of central and western United States, America being the original home of the horse. The earliest member of the series directly leading up to the horse was *Eohippus*, an older eocene form, about as large as a fox, which had four well-developed toes and the rudiments of a fifth on each fore-foot, and three toes behind. In later eocene beds appeared an animal (*Orohippus*) of similar size, but with only four toes in front and three behind. In newer beds, *i. e.*, lower miocene, are found the remains of *Mesohippus*, which was as large as a sheep and had three toes and the splint of another in each fore-foot, with but three toes behind. In later miocene beds another form (*Anchitherium* or *Miohippus*) had the same number of toes, but with the "splint bone of the outer or fifth digit reduced to a short remnant." The splint bones, then, represent two of the digits of several-toed animals. The succeeding forms were still more horse-like. "In the Pliocene above, a three-toed horse (*Hipparion* or *Protohippus*), about as large as a donkey, was abundant, and still higher up a near ally of the modern horse, with only a single toe on each foot (*Pliohippus*) makes his appearance. A true *Equus*, as large as the existing horse, appears just above this horizon, and the series is complete." (Marsh.) Fossil horses extended over portions of North and South America, but became extinct before the present Indians appeared.

The horse (*Equus caballus* Linn.) is the most useful of all domestic animals, and next to ships a prime means of the diffusion of civilization. By artificial selection a great number of varieties, races, and strains have been produced, adapted for the performance of different kinds of work. The horse only exists in a domesticated state. Sanson states that

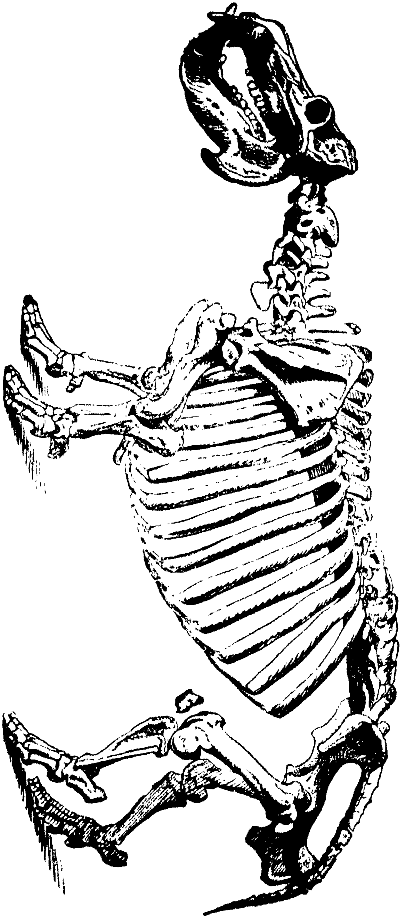

Fig. 522.—Skeleton of the Hippopotamus.—From Brehm's Thierleben.

the horse in the Orient has five, and in the west (Africa) six lumbar vertebræ; in Arabia both forms occur; in the horse with but five lumbar vertebræ the shape of the skull is also different. The *Hemippus*, the *tarpau* and *muzir* of Tartary, as well as the white, shaggy horse of the elevated plains of Pamir in central Asia which is often regarded as the original stock, may be a race which has returned to a wild state, since partly wild horses occur in Syria, on the Don, and live in great herds on the llanos and pampas of South America. There are two primitive races of horses, the Oriental and Western. To the first belong three types: the Arabian, with the Berber, Andalusian, Neapolitan; and in England the blood horse; the Nizaischan type of the Deccan, India, to which belong the Persian, Turkestan, Turkish horses, and the Tartarian. The western races comprise the Frieseland, to which belong the Brabant, Holstein, Mecklenburg, and the English farm-horse, and among others the Percheron horse, of France. Ponies are dwarf horses produced in cool, mountanous areas, such as the Shetland Islands. The wild ass (*Equus onager* Brisson) ranges from the Indus to Mesopotamia. *Equus hemionus* Pallas, the Dschiggetai or Kiang, goes in herds in central Asia and Mongolia. The hinny and

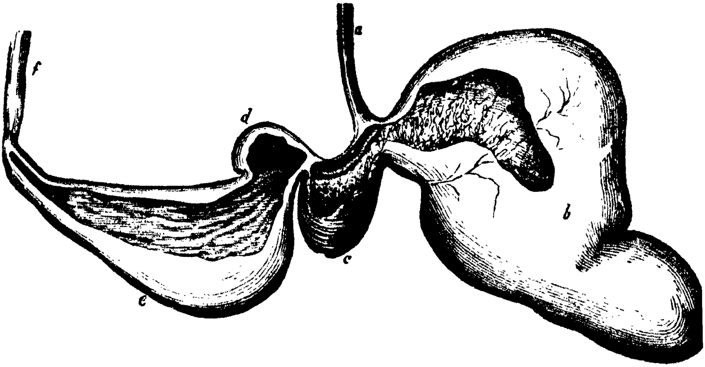

Fig. 523.—Stomach of a ruminant (sheep), showing the four compartments; *a*, œsophagus; *b*, paunch; *c*, honeycomb or reticulum; *d*, liber psalterium or manyplies; *e*, true digestive stomach; *f*, beginning of the intestine.—After Owen.

mule are infertile hybrids of the horse and ass (*Equus asinus* Linn.).

Artiodactyles.—The even-toed Ungulates comprise the peccary, pig, hippopotamus, and the Ruminants represented by the deer, sheep, ox, and camel. The pig and peccary are the descendants of a number of extinct earlier forms which flourished in the Tertiary Period; the pig, as Marsh observes, having held its own with characteristic pertinacity. The *Hippopotamus* (Fig. 522) has a large head, with large canines, a clumsy body, and short, three-toed legs. *Hippopotamus amphibius* Linn., ranges from the Upper Nile to the Cape of Good Hope, and westward to Senegambia. It is nearly 3½ metres (11 feet) in length.

Ruminantia.—The remaining Artiodactyles are called Ruminants, from the fact that they chew their cud. The molars are provided with two double crescent-shaped folds (compare Fig. 490). The stomach (Fig. 523) is divided into at least three, usually four compartments, *i.e.*, the paunch, the *reticulum* or honeycomb, so named from the polygonal cells on its interior, the *psalterium* or manyplies, and lastly the rennet or true stomach. When a sheep, cow, or any other Ruminant feeds, it thrusts out its long tongue, seizes a bunch of grass, and bites it off by pressing the incisors of the lower jaw against the toothless gum of the opposing part of the upper jaw; the mouthful of grass is then swallowed, mixed with much saliva. When its appetite is satisfied it seeks a retired spot away from its carnivorous enemies, if not a domesticated animal, and after lying down, suddenly regurgitates a ball of grass, the cud,* which it slowly grinds up between its molar teeth into a pulp. The cropped grass passes into the honeycomb and paunch; the manyplies serves as a strainer for the pulp, which in the fourth stomach is digested by the gastric juice.

Among a number of fossil forms leading up to the exist-

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* The regurgitation of the cud is probably due to a sudden and simultaneous contraction of the diaphragm and of the abdominal muscles, which compresses the contents of the rumen and reticulum, and drives the sodden fodder against the cardiac aperture of the stomach, which opens and the cud is propelled into the mouth. (Huxley.)

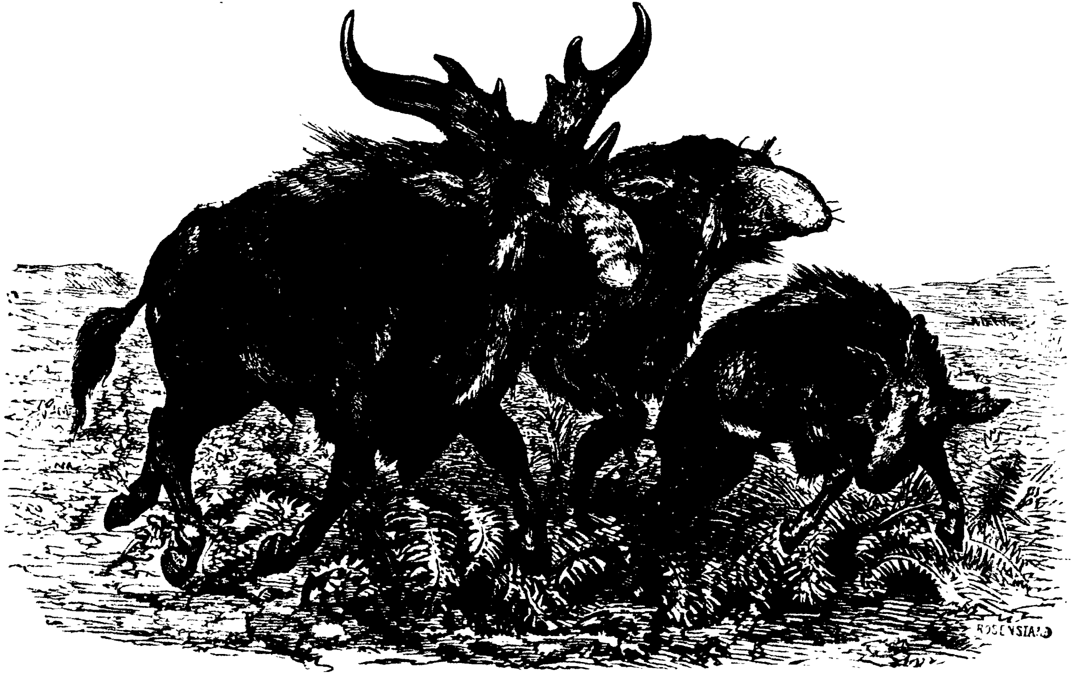

Fig. 594. Restoration of buck, doe, and young Sivatherium. After Hawkins.

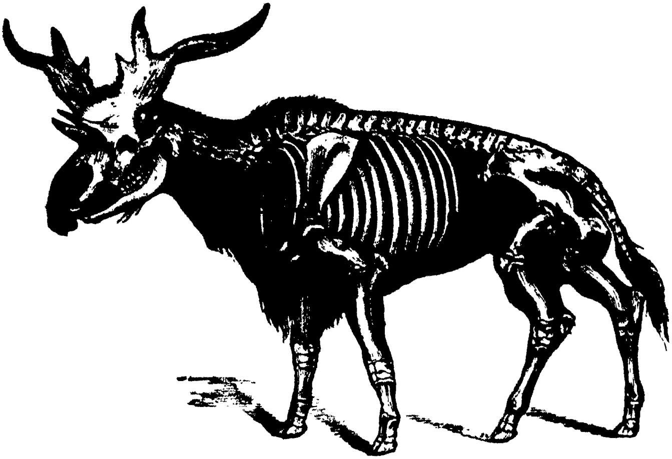

Fig. 525.—Skeleton of Sivatherium restored.—After Hawkins.

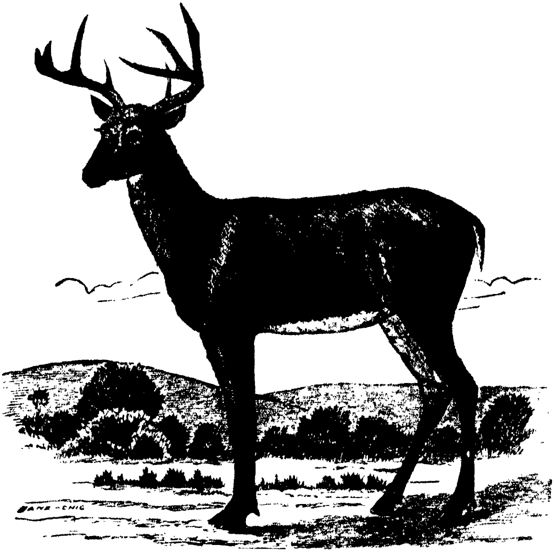

Fig. 526.—Virginian Deer.—From Caton.

ing deer and antelopes is the *Sivatherium* (Fig. 524, 525) of the Tertiary beds of the Himalaya Mountains, which had two pairs of horns, and were gigantic creatures, nearly as bulky as an elephant, and of the singular form approximately indicated by the accompanying illustrations, having affinities to the antelopes and the giraffe.

. 527.—Elk or Wapati.—From Caton's Antelope and Deer of America.

The deer family (*Cervidæ*) is represented in the United

States by the common Virginian deer (*Cariacus Virginianus* Gray, Fig. 526), the elk or wapiti (*Cervus Canadensis* Erxleben, Fig. 527), and the caribou (*Rangifer caribou* Audubon and Bachman), which is probably a variety of the European reindeer (*R. tarandus* Sundevall). In these beautiful, graceful forms the solid antlers are cast off annually; with the exception of the reindeer the females or does have no antlers.

The prong-horn antelope (*Antilocapra Americana* Ord. Fig. 528) so characteristic of the western plains, also drops its horns in the autumn, though they are hollow when shed and with a persistent core as in the ox and goat. It crops grass, not, like the deer, eating leaves of trees and shrubs; "in fleetness it excels all other quadrupeds of our continent," though it is short winded, and does not run a great distance (Caton). In its horns, hollow when cast off, and the gall bladder, which is absent in the *Cervidæ,* the prong-horn

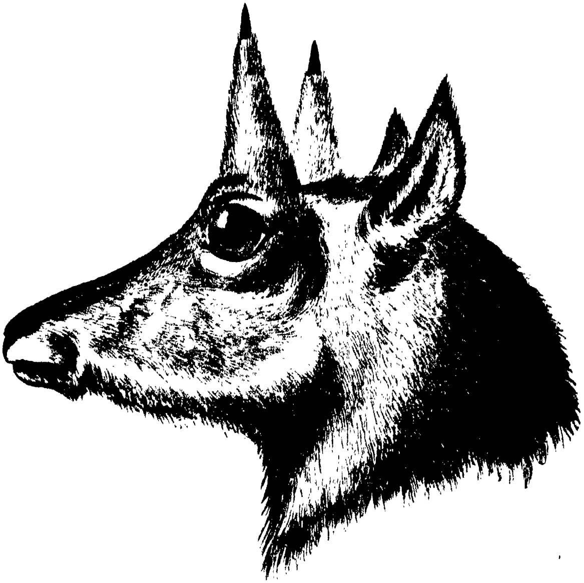

Fig. 528.—Head of young Prong-horn Antelope.—After Hays.

connects the deer family with the *Bovidæ,* represented by the sheep, goat, antelope, gazelle, and ox.

The domestic sheep (*Ovies aries* Linn.) is not a natural species, but an association of races whose specific origin is obscure. Some authors regard the turf sheep of the stone age of Europe as the ancestor of the domestic sheep, as forms like it are now living in the Shetland Isles and in Wales. It was of small size, with slender limbs, and erect, short horns. This sheep was supplanted by a curved, large-horned form, the modern domestic sheep. This latter form is possibly the descendant of the *Ovis argali* Pallas, of Asia, which in North America is represented by the *Ovis montana* Cuvier, the Rocky Mountain sheep or big-horn (Fig. 530), still common on the less accessible summits along the upper Missouri and Yellowstone Rivers, as well as the mountains of Wyoming and Montana.

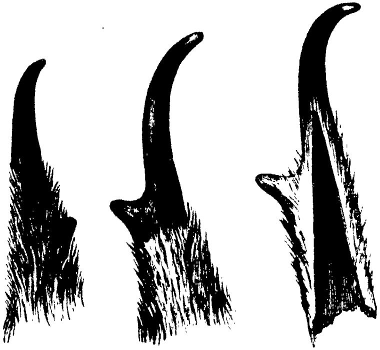

Fig. 529.—Horns at different ages of the Prong-horn Antelope, showing the hollow structure of the horn when shed.—After Hays.

In the same, though higher and more inaccessible situations lives the rare mountain goat, *Aplocerος montanus* Richardson, whose horns are jet black and polished, slender and conical, like those of the Swiss chamois. It is found sparingly in the higher summits of the Rocky Mountains and the Cascade range; an individual has within a few years been shot on Mount Shasta, California. Passing by the gazelles and true antelopes we come to another characteristic American animal, the musk sheep (*Ovibos moschatus* Blainville, Fig. 531), now confined to the arctic regions. A closely allied species, *Ovibos priscus* of Rütimeyer, formerly during the post-glacial period existed in England, France, and Germany. Closely allied to the musk sheep is a fossil form (*Boötherium* of Leidy) which is regarded by Rütimeyer and others as a musk sheep (*Ovibos priscus* Rütimeyer). If this is the case the musk sheep, or a species closely allied to it, formerly extended to the Middle States at or near the close of the glacial period.

We now come to the bison and ox. The American bison (*Bison Americanus* Gmelin) formerly ranged from Virginia and Lake Champlain to Florida, and westward from the northern limit of trees to the Rocky Mountains and eastern Mexico. It is now in danger of extermination, being mainly restricted to a few herds on the plains. It is closely

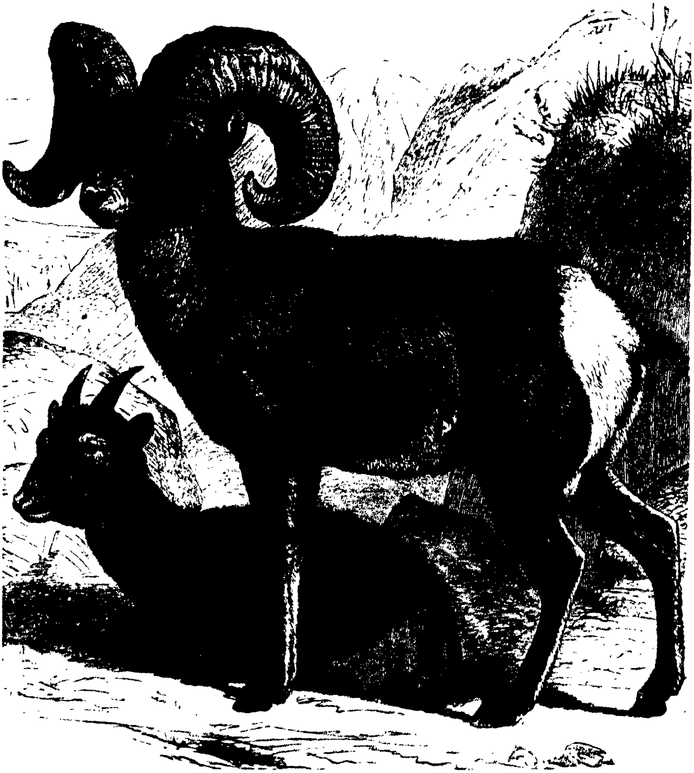

Fig. 580.—Rocky Mountain Sheep or Big-Horn.—From Brehm's Thierleben.

allied to the European bison, (*Bison Europæus* Owen), the "auroch," now preserved in the forests of Bialowicza, and living wild in Caucasus. *Bos primigenius* Bojanus, which

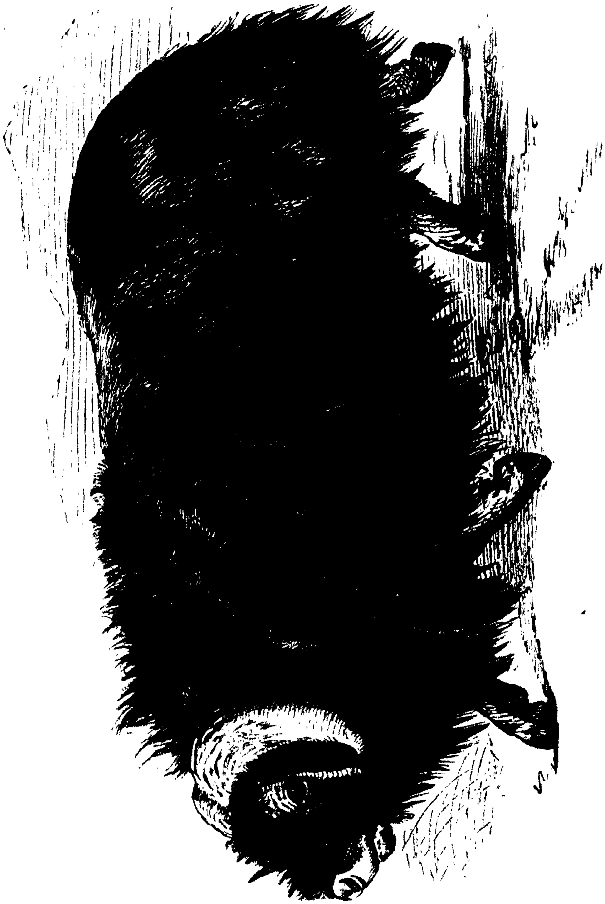

Fig. 531.—Musk Sheep.—From Brehm's Thierleben.

in the time of Cæsar lived in Germany and England bearing the name "urus," is the "ur" of the Niebelungen song. From it has descended the half-wild cattle in certain

English parks, also certain large domestic races, such as the Holstein and Friesland breeds. From another fossil species (*Bos longifrons* Owen) arose the so-called brown cattle of Switzerland, and the "runts" of the Scottish Highlands. Still other domestic races are traced back to another fossil quaternary species, *Bos frontosus* Nilsson. Our present races of domestic cattle, however, do not represent a genuine species, but a number of races which have descended from several fossil species; the name *Bos taurus* (Fig. 532) is simply, then, a conventional name (Carus' Zoologie). The bison is known to breed with cattle in the Western States,

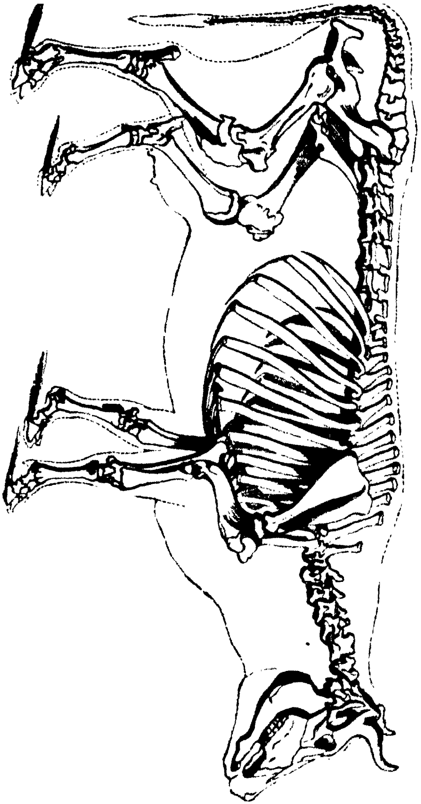

Fig. 532.—Skeleton of Domestic Cow.—After Owen.

though whether the hybrids thus produced are fertile or not is unknown.

The ox is succeeded by the giraffe, with its long neck, which makes it the tallest of all quadrupeds.

The last family of Ungulates, the *Camelidæ*, comprises the camels of the Old World, and the llama and vicuna of South America. In former (Tertiary) times a llama-like animal inhabited the Pacific coast to Oregon. In the camels the upper lateral incisors are present; the stomach is less distinctly divided into four chambers, the third stomach, as such, is wanting, though the second stomach has the deep cells, which suggested the fable that the camel stores up a supply of water in its stomach for its march over deserts.

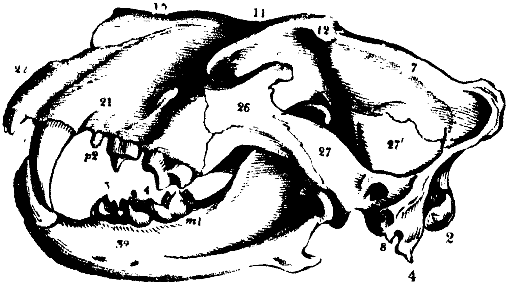

Fig. 533.—Skull of Lion.

The toes have very large, thick pads, while the hoofs are reduced to nail-like proportions.

Order 11. *Carnivora* (*Feræ*).—The bear, cat, tiger, and lion recall the leading forms of this order. The skull is massive, though the head is small or of moderate size; the teeth are all well developed, especially the canines; the molars usually have two or three roots, and the feet have large claws. The stomach is simple. The cerebral hemispheres of the lower carnivores have usually but three distinct convolutions, while the latter are much more numerous and complicated, the brain itself being broader, in the aquatic forms (*Pinnipedia*). The group is divided into two sub-orders, *i.e.* the Pinnipedia or seals, and the land species (*Fissipedia*). In the former group the feet are webbed, the toes being connected; the wrist and foot only projecting beyond the skin of the body, and there are no external ears, or only small ones.

The walrus (Fig. 534), the seals, and the eared seals or sea-lions (*Otariidæ*) are the types of the aquatic Carnivores; the sea-lions can walk on all fours, and in certain peculiarities of the skull they resemble the bears.

Of the terrestrial, normal *Carnivora*, the raccoon, coati, *Cercoleptes*, and bear, together with a number of extinct forms, are the more generalized or lower types. They are plantigrade, and while standing at the base of the carnivorous series, have some features suggesting and anticipating those of the lemurs, and monkeys. The raccoon, *Procyon lotor* (Linn.), abounds throughout the United States. Allied to it is the coati (*Nasua*) of Central America, a creature about the size of, and with the general habits of the raccoon, being an exceedingly knowing and mischievous animal. A number of extinct Eocene mammals are also allied to a small plantigrade, long-tailed carnivore, *Cercoleptes*, which resembles the *Primates* in its two cutting

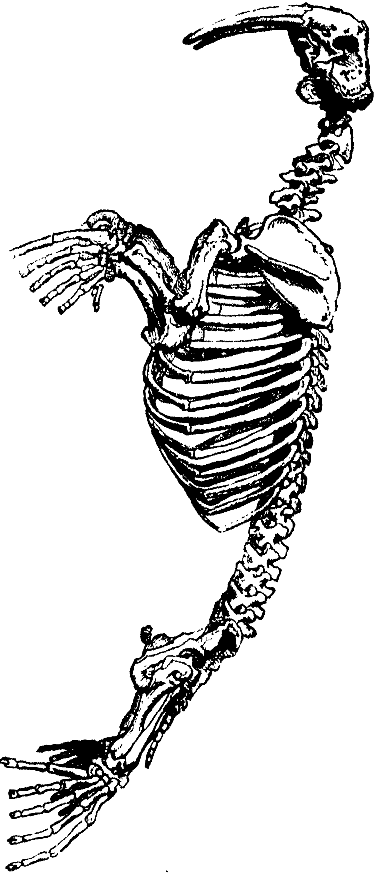

Fig. 534—Skeleton of the Walrus.—From Brehm's Thierleben.

pre-molars and three true molars; while the rami of the mandible are coössified; for these reasons it was placed by F. Cuvier between the orders *Carnivora* and *Primates* (Cope). It is allied to the raccoon, is called the kincajou, and lives in northern South America.

The bears have a thick, clumsy body, with a rudimentary tail, and the teeth are broad and tuberculated, so that they can live indifferently on fish, insects, or berries. Our North American species are the polar bear (*Ursus maritimus* Linn.) and *Ursus arctos* Linn., with its varieties of brown, cinnamon and grizzly bears; and the true black bear, *Ursus Americanus* Pallas.

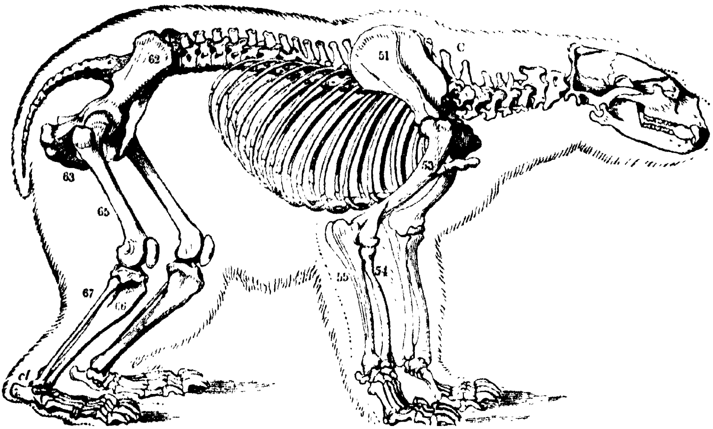

Fig. 585.—Skeleton of the Polar Bear, showing the plantigrade feet. 51, scapula; 53, humerus; 54, radius; 55, ulna; 62, ilium; 63, ischium; 65, femur; 66, tibia; 67, fibula; *cl*, calcareum; C, cervical vertebræ.—After Owen.

The bears are succeeded by the *Mustelidæ*, or the otter, skunk, badger, wolverene, weasel, mink, ermine, etc., nearly all of which are valuable for their furs.

The dog family (*Canidæ*) is represented by the fox, wolf, and dog. The gray fox (*Urocyon Virginianus* Erxleben) the common red fox (*Vulpes vulgaris* Fleming), with its varieties, the cross, silver, and black fox, as well as the wolf (*Canis lupus* Linn.), are valuable for their furs. The wolf is mostly gray northward, becoming "southward more and more blackish and reddish, till in Florida black wolves predominate, and in Texas red ones." (Jordan's Manual of Vertebrates.) The prairie wolf or coyoté (*Canis latrans* Say), is characteristic of the Western plains and Pacific coast. The Indian dogs breed with the coyoté, and the offspring is fertile. (Coues.) This fact appears to support the theory that the domestic dog (with its conventional name *Canis familiaris* Linn.) is a descendant of the wolf. On the other hand, Fitzinger in his "Researches on the Origin of the Dog," states that fourteen kinds of dogs can be distinguished in the Roman and Greek records; of these he considers five to be principal types or species, five others climatic varieties, the remainder being either breeds artificially produced or hybrids. As regards the Egyptian dogs, seven kinds may be distinguished, besides the jackall, three of them being distinct species. He believes that wolves, jackalls, foxes, etc., are species quite distinct from the domestic dog; they may have interbred with the latter, and thus influenced certain breeds; but they are not the parents of the domestic dog. He concludes that there are seven species among our dogs:—*C. domesticus, extrarius* or spaniel and Newfoundland dogs, *vertagus* or badger dog, *sagax* or hound, *molossus* or bulldog, *leporarius* or greyhound, and the naked dog, *C. caribæus*. Among half-wild dogs is the dingo or hunting-dog of Australia, which goes in packs.

The *Viverra* and *Genetta* or civet cats, and the hyænas lead to the cat family, which stands at the head of the Carnivora. The panther, leopard, tiger, and lion belong to the genus *Felis*. The *Felis concolor* Linn., cougar or puma, ranges over both continents; it is 1–1·3 metres in length. The domestic cat, *Felis domestica* Linn., was first domesticated in Egypt, the Greeks and Romans not possessing it; the cat and common marten were in use as domesticated animals side by side; and at the same time in Italy, nine hundred years before the crusades. It appears that the domestic cat of the ancients was *Mustela foina* (Rolleston).

Of the lynxes there are two species in North America, *Lynx rufus* Rafinesque, the American wildcat, and the Canada lynx, *Lynx Canadensis* Rafinesque, the latter being much the larger species.

Order XII. Primates.—The last and highest order of mammals contains a series beginning with creatures resembling squirrels and bats, *i. e.*, the lemurs, and comprising monkeys, apes, and ending with man. In all the *Primates*, the legs are exserted almost or quite free from the trunk, with the great toe of the hind foot usually enlarged and opposable to the others; nails, except in the marmosets, replace claws; the teeth are usually of the following formula:

$$I\frac{2-2}{2-2},\ C\frac{1-1}{1-1},\ P\frac{3-3}{3-3},\ M\frac{3-3}{3-3};$$

with one exception canine teeth are always present; the premolars are usually $\frac{2-2}{2-2}$, but in the American monkeys $\frac{3-3}{3-3}$.

The hemispheres of the brain may in the lower forms be quite smooth, but in all there is a well-developed "calcarine furrow," giving rise to a "*hippocampus minor*" within the posterior *cornu* of the ventricle, by which the posterior lobe of the cerebrum is traversed (Flower). The collar-bones (clavicles) are for the first time in the series well developed. The placenta is also different in shape from that of other mammals, being round, disk or cake-like.

The *Primates* are divided into two sub-orders, *i. e.*, the *Prosimiæ* and *Anthropoidea.* The former group embraces the lemurs, which vary in size from that of a rabbit to a large monkey. They are covered, the face as well as the rest of the body, with a dense fur; walk on all-fours, usually have long tails, though the lori is tailless, while the fore limbs are shorter than the hind limbs. The skull is small, flattened, and narrow in front; the brain-cavity small in proportion to the rest of the skull, *i. e.*, the face compared with the monkeys. The cerebral hemispheres are small and flattened, the frontal lobes narrow and pointed, and behind they only slightly cover the cerebellum.

By some authors the lemurs are separated from the *Primates*, the *Insectivora* and *Cheiroptera* being placed between the *Prosimiæ* and the other *Primates*. They have characters in which they resemble *Insectivora*, *Rodentia*, and *Carnivora*, but the weight of organization, or the sum of their characters, ally them nearest to the monkeys. They are therefore essentially a generalized or ancestral type. Recent discoveries have led to the hypothesis, that from still older, more generalized types, four lines of development, respectively culminating in the typical Carnivores, Cetaceans, lemurs, and monkeys, have taken their origin. That the lemurs, though now restricted to Madagascar, eastern Asia, and South Africa, were preceded by still more generalized types on the American Continent, is indicated by the discovery of fossil bones in the Eocene beds of the Rocky Mountains, referred by Marsh and Cope to the Primates; Marsh stating that the principal parts of the skeleton are "much as in some of the lemurs."

Allied to the true lemurs is a very puzzling creature, the aye-aye or *Chiromys*, of Madagascar, whose dentition differs from that of all other *Primates*, and resembles that of the Rodents; the thumb also is not truly opposable, and all the hind digits, except the great toes, have claw-like nails. The *Galago*, of West Africa, somewhat recalls the *Insectivora*, while "in the more active and flexible-bodied *Lemuridæ*, the trunk-vertebræ resemble in proportions, connections, and direction of neural spines those of the agile *Carnivora*." (Owen.)

The genuine *Primates* or suborder *Anthropoidea* are, in brief, characterized by the large, convoluted cerebral hemispheres which nearly, or in the higher apes and man, conceal the cerebrum when seen from above.* The ears are rounded, with a distinct lobule, and the two mammæ are pectoral. These *Anthropoidea* are divided into two subdivisions, the first comprising the monkeys and apes, and the second, man. In the first group (*Simiæ*), the body is prone, the animal walking on all-fours, only the orang and gorilla walking partly erect; the great toe is rather short, thumb-like, and opposable to the fingers, while the body is very hairy. The monkeys of the New World have a wide septum to the nose, and are hence called *Platyrhinæ*; they also have long tails.

The little, squirrel-like, gregarious marmosets are the smallest of the monkeys and nearest allied to the lemurs. They walk on all-fours, the anterior extremities being like the

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*** In the low *Hapale* and *Cebus*, however, the cerebrum projects backward as far or even farther than in man (Gill).**

hind feet, and resting on the same plane, serving as a paw; the teeth are sharply tubercled, and the nails, except those of the great toe, are claw-like. The cerebral hemispheres are nearly smooth, though relatively large. *Jacchus* and *Midas* are the typical genera, inhabiting South America. While the marmosets (*Mididæ*) have but thirty-two teeth, in the true platyrrhine monkeys there are thirty-six teeth; there being an additional molar on each side of each jaw, and the thumb is slightly opposable to the fingers (though a true thumb is wanting in the spider monkeys). The New World monkeys also have long prehensile tails, so useful in climbing as to be sometimes called a fifth hand, as seen in the spider monkeys (*Ateles*), in which the tail underneath is naked and very sensitive. The skull varies greatly in the different genera, as does the brain, which in *Chrysothrix*, etc., is nearly smooth, while in *Cebus* the hemispheres are nearly as much convoluted as in the catarrhine apes. (Huxley.)

The monkeys of the Old World intergrade with the apes, and are thus more specialized or highly developed than those of the New World. The septum of the nose is narrow, hence they are said to be *catarrhine* or thin-nosed, while the tail is short and not prehensile.

The catarrhine monkeys (*Cercopithecidæ*) walk on all-fours; the body being horizontal or prone; they have thirty-two teeth, as in man, though the canines are large and sharp; the thumb is well developed, and they are truly quadrumanous; the skull has a comparatively large facial angle, and the hemispheres of the brain are well furrowed. They have highly-colored, naked callosities over the ischiatic bones, and cheek-pouches for the temporary reception of the food. Of the baboons, with their dog-like muzzles and short tails, the mandrills are the most noticeable, with their white beards, scarlet lips, and blue cheeks; they are less arboreal than the macaques of Asia, running about over rocks on all-fours. The common monkeys of menageries are the macaques (*Macacus*) of India. All the foregoing catarrhine monkeys have a simple stomach, as in man, but in the sacred monkey of India (*Semnopithecus*) and the African thumbless *Colobus*, the stomach is more complex, and there are no cheek pouches.

The apes live in trees, only occasionally walking on the ground; their posture is semi-erect; they are tailless, the fore legs are much longer than the hind legs, and used as arms, the radius being capable of complete pronation and supination. In the form of the skull, of the brain with its convolutions, and in the teeth, there is a still nearer approach to man.

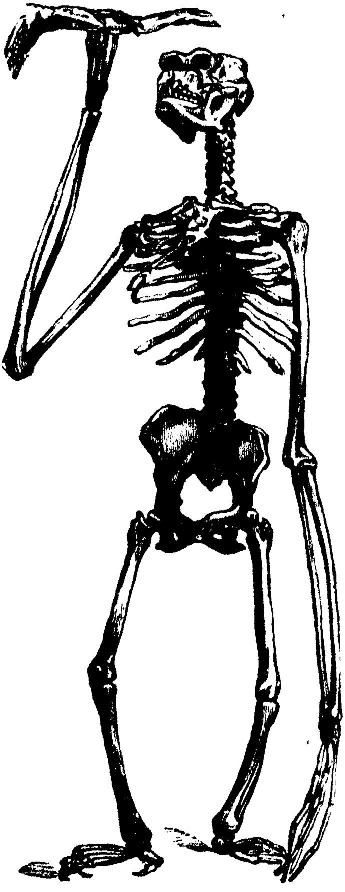

Fig. 536.—Skeleton of Siamang Ape, a gibbon.—After Owen.

There are three typical forms or genera of apes, *i.e.*, the gibbon (*Hylobates*, Fig. 536); the orang (*Mimetes pithecus*) and chimpanzee (*M. niger*, Fig. 537), and the gorilla. The gibbons are nearest to the monkeys; they are little less than a metre (3 feet) in height, and are very slender, with very long arms, so that they are rapid, agile climbers, also running over the ground with ease and rapidity; when standing erect the fingers touch the ground; only the thumbs and great toes have true nails, in all the higher apes the nails of all the digits being flattened; the spinal column is nearly straight; they have fourteen pairs of ribs and eighteen dorso-lumbar vertebræ, there being in the other apes usually seventeen, as in man. The siamang lives in the forest of Sumatra; others inhabit Java, Borneo, Cambogia, etc.

The orang-outang is 1·38 metres (4½–5 feet) high; it has twelve pairs of ribs, the same number as in man; the arms are very long, reaching the ground, so that in walking they rest on their knuckles, swinging the body through their long arms as if walking on crutches; their posture is only partially erect. The forehead is less strongly marked than in the other apes, showing better the shape of the skull. The volume of the brain, both of the orang and chimpanzee is about twenty-six or twenty-seven cubic inches. The following table will show, according to Wyman, the relative capacity of the skull in the different apes as compared with man:

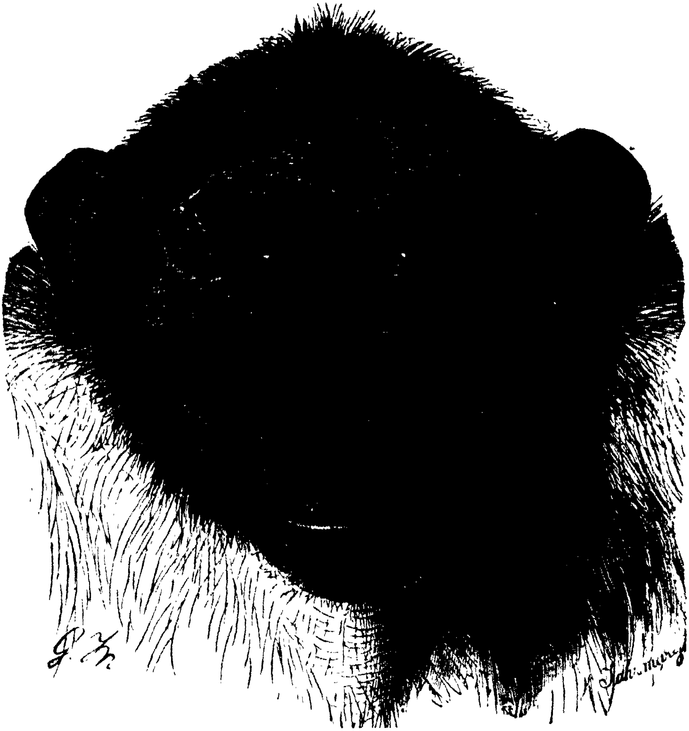

Fig. 537.—The Chimpanzee, variety Tshego.—From Brehm's Thierleben.

The average capacity of the Caucasian skull is 92 cubic inches.
" " " Australian " 75 "
" " " Gorilla " 29 to near 35 cubic inches.
" " " Chimpanzee " 26 "
" " " Orang " 25 "

According to Wyman, the range of variation in different races of men, as seen in seventeen skulls, is from 92 to 75 cubic inches; in the gorilla from 34 to 25 cubic inches, nine skulls having been measured. There is but a single species of orang, which is restricted to Sumatra and Borneo. It is said to be very intelligent, to possess a voice so loud as to be heard one or two miles, and to build a nest to sleep in.

The chimpanzee and gorilla are only found on the west coast of Africa. The chimpanzee (*Mimetes niger* Geoffroy with its variety *Tschego*, Fig. 537) inhabits the coast from Sierra Leone to Congo. It is about 1½ metres (5 feet) in height. It can stand or run erect, but it usually leans forward, resting on its knuckles; the arms span about half as much again as the creature's height. Both the chimpanzee and gorilla have fourteen pairs of ribs. The chimpanzee lives on fruit, is an active climber, and nests in trees, changing its rude quarters according to circumstances. Rev. Dr. Savage states that "they generally build not far above the ground. Branches or twigs are bent, or partly broken, and crossed, and the whole supported by the body of a limb or a crotch. Sometimes a nest will be found near the *end* of a *strong leafy branch* twenty or thirty feet from the ground."

The gorilla, like the chimpanzee, goes in bands, but the company is smaller, and led by a single adult male. They make similar nests, which, however, in the case of both apes, afford no shelter, and are only occupied at night. The gorilla sometimes reaches the height of about 1⅓ metres (5½ feet) and weighs about 200 pounds. Its ordinary attitude is like that of the chimpanzee; there is a web between the first joints of all the fingers and three of the toes, and both hands and feet are broader, while the body is much more robust than in the other apes, being very broad across the shoulders. The span of the arms is to the height as three to two, or a little over eight feet. The skull is thick, and the strength and ferocity of the creature is evinced by the thick supra-orbital ridges and the high sagittal and lambdoidal crests on the top of the skull; the face is wide and long, the nose broad and flat, the lips and chin prominent. The gorilla walks like the chimpanzee, though it stoops less. It is very ferocious, bold, never running when approached or attacked by man. It lives on a range of mountains in the interior of Guinea, its habitat, so far as known, extending from a little north of the Gaboon River to the Congo.

Thus, to recapitulate, while the gibbons are most remote from man, the orangs approach him nearest in the number of the ribs, the form of the cerebral hemispheres, and other less obvious characters; the chimpanzee is nearest related to him in the form of the skull, the dentition and the proportions of the arms, while the gorilla resembles him more in the proportions of the leg to the body, of the foot to the hand, in the size of the heel, the curvature of the spine, the form of the pelvis and the absolute capacity of the skull (Huxley). Anatomists have and do differ as to whether the chimpanzee or the gorilla is nearest to man.

Whether man (*Homo sapiens* Linn.), when considered simply as an animal, is the representative of a distinct subclass, order, suborder or family, is and may never be settled; though the tendency among zoologists is to leave him among the *Primates*, where he was placed by Linnæus. When we consider the slight absolute anatomical differences separating man from the apes, and take into account the great variations in form between the different genera of apes, and still more in the monkeys, it seems best, throwing out, as we have to do in a purely zoological classification, the intellectual and moral faculties of man, to adopt the view that man is the representative of a group of *Primates*.* The absolute differences of man from the apes consist in the greater number and irregularity of the convolutions of the cerebral hemispheres, which are also much larger compared with the cerebellum, and completely cover the latter; the entire brain being at least double the size proportionately of that of the gorilla;* it is also stated that two muscles exist in man which have not yet been found in any ape, the *extensor primi internodii pollicis* and the *peronæus tertius*, belonging to the thumb and foot respectively (Huxley).† There are also points in the origin of certain muscles which are peculiar to man, but Huxley adds that all the apparently distinctive peculiarities of the muscles of the apes are to be met with, occasionally, as varieties in man. On the other hand, the relative differences of the skulls of the gorilla and man are, as Huxley states, "immense." In man the cranial box overhangs the orbits; in the gorilla the forehead is hollowed out. The hinder portion of the brain is also much more developed in man than in the apes, and in the hinder part of the hemispheres the convolutions are more numerous than in the chimpanzee, this part in monkeys losing its convolutions altogether (Wyman). Man stands erect; his arms span a distance equal to his height; the spinal column has four curves; the skin of the hands and feet of man is highly sensitive, compared with that of the apes. Finally, as Cuvier stated, the grand distinctive zoological character separating man from the other animals is the possession of the power of speech.

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* Geoffroy St. Hilaire placed man in a kingdom by himself; Owen assigned him to a subclass; by others he is generally regarded as a representative of an order *Bimana*, as opposed to the order Quadrumana, or monkeys and apes; while from recent comparative studies man is considered as belonging either to a separate suborder or a family.

Sometimes in man the coccyx has one or two more joints than the normal number, but the apes have no tail; though the human embyro, like other young animals, has a tail, and, as Wyman has observed, it is not impossible that it might sometimes continue to exist after birth. The black and Australian races are slightly nearer the apes than civilized peoples. In apes, as in the lower mammals, the pelvis is higher than wide; when there is a degradation in the human pelvis it tends to become higher than wide, as seen in the pelvis of the Hottentots. In civilized man the legs are one half the height of the body, but in the South African, Hottentot, and Bushmen the legs are a little less than half the height, and the thigh bone is flattened from side to side, as in the gorilla. The waist is broader in the African than in the European; the *os calcis* is not longer in negroes than in the white man, the larger heel of the former being simply due to an expansion of the soft parts.

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* "It must not be overlooked, however, that there is a very striking difference in absolute mass and weight between the lowest human brain and that of the highest ape—a difference which is all the more remarkable when we recollect that a full-grown gorilla is probably pretty nearly twice as heavy as a Bosjes man, or as many an European woman. It may be doubted whether a healthy human brain ever weighed less than thirty-one or two ounces, or that the heaviest gorilla brain has exceeded twenty ounces." In another place Huxley states that "an average European child of four year's old has a brain twice as large as that of an adult gorilla."—*Man's Place in Nature.*

† Dr. Chapman has found in the arm of a gorilla a distinct *extensor primi internodii pollicis* muscle, but no trace of the *flexor longus pollicis.*—*American Naturalist*, June, 1879, p. 395.

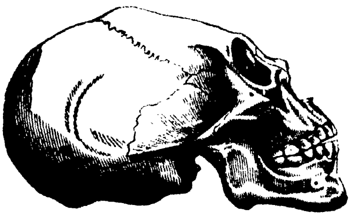

Fig. 538.—Skull of a Negro, showing its prognathism.—After Owen.

The form of the skull varies greatly in the different races, and even in individuals of the same race of mankind. This is seen in the difference of the *facial angle*. This is obtained by drawing a line from the occipital condyle along the floor of the nostrils, and intersecting it by a second, touching the most prominent parts of the forehead and upper jaw; the angle they make is an index of the cranial capacity, and of the degree of intelligence of the individual. The facial angle in the reptiles is very slight, as it is in the birds; in the dog it is 20°, in the gorilla 40°, in the Australian 85°, in the civilized Caucasian it averages 95°, while the Greek sculptors adopted an ideal angle of 100°. (Owen.*) When the lower part of the face protrudes, as in the negro, the face is said to be *prognathous* (Fig. 538); where the facial angle is high, and the face straight, as in the more intellectual forms, the cranium is said to be *orthognathous.* Those skulls which are high and narrow, *i.e.*, with the longer diameter to the shorter, as 100 to 65, are said to be *dolichocephalic*, while those with the diameters as 100 to 85 are called *brachycephalic*, but these distinctions have been found to be quite arbitrary.

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* Pagenstecher states that the facial angle in the Caucasian European is 80°–85°, and even over 90°; in the Mongolians 75°–80°; in negroes 70°–75°; in the tribe of Makoias in South Africa 64°; in the tribe of Tikki-Tikki, or Akka negroes, the dwarfs described by Schweinfurth, only 60°.—Allgemeine Zoologie, i., p. 250.

The classification of the human races is in as an unsatisfactory state as that of the domestic animals. Naturalists are now agreed that there is but one species of man. Blumenbach, from the shape of the skull and the color of the skin, divided mankind into three varieties, the white or Caucasian, the brown or Mongolian, and the black or Ethiopian, considering the American variety as connecting the Caucasian and Mongolian, and the Malayan as intermediate between the Caucasian and Ethiopian. Hamilton Smith divided man into three varieties, Caucasian, Mongolian, and Tropical; Latham, also, into three, Japetidæ, Mongolidæ, and Atlantidæ; and Pickering into white, brown, and black varieties, with intermediate races. Huxley divides the different races into two primary groups, the *Ulotrichi*, with crisp or woolly hair, and the *Leiotrichi* with smooth hair.

The average height of Englishmen is 5·8–5·10 feet; in the universities more. In America, the average height of medical and military men is 5·9¾ feet. The Patagonian men are nearly six feet high on an average; the women 5·10 feet; the Bushman and Esquimaux 4·7, the latter being the smallest people on the earth. The smallest dwarfs in Europe were 33 and 28 inches in height respectively; while Patrick Cotter, the Irish giant, was 8 feet 7 inches tall.

It is claimed by some naturalists that man has descended from some generalized type of animal which gave rise to several series of forms culminating in the monkeys, apes, and man respectively, and by others that he is a direct descendant of forms like the chimpanzee or gorilla; but it is probable that from the want of sufficient data, the question as to the origin of man can never be definitely settled. Setting hypothesis aside, in ascending the mammalian series, we have seen in the forms leading from the extinct Eocene generalized types of *Educabilia* to the *Carnivora* and *Primates*, a tendency to an extreme specialization of those parts ministering to the intellectual behests of the creature. On the other hand, in all general points, man's limbs are those of the primitive type so common in the Eocene Period. As Cope remarks: "He is plantigrade, has five toes, separate carpals and tarsals; a short heel, rather flat astragalus, and neither hoofs nor claws, but something between the two. The bones of the fore arm and leg are not so unequal as in the higher types; and remain entirely distinct from each other, and the ankle joint is not so perfect as in many of them. In his teeth his character is thoroughly primitive. He possesses, in fact, the original quadrituberculate molar with but little modification. His structural superiority consists solely in the complexity and size of his brain."

Whether man in common with other animals is the result of divinely ordered processes of biological laws, appearing at the head of a long series of forms, and, as probably many other animals have, with comparative suddenness, being at the outset in all essential respects *man*, though a savage, and not with a long pedigree of morphologically impossible Darwinian "missing links,"—whether he thus originated, or by an independent creative act, the result is a being concerning whom the fact that he is physically an animal, is after all the least important characteristic of the nature of him who is the historian of his own and other species; who is capable of studying and in a degree comprehending the universe in which he lives, and who whatever his physical origin may have been, has intellectual, moral, and spiritual capabilities which render his nature susceptible of endless improvement, endowing him with immortality and all that it involves.

Class VII.—Mammalia.

Body covered with hair; young nourished with milk secreted in mammæ; lower jaw articulating directly with the skull, the quadrate bone becoming one of the ear-bones (malleus); a diaphragm dividing the body-cavity into thoracic and abdominal portions; heart with the aorta reflected over the left bronchus; blood-corpuscles non-nucleated; brain large, especially the cerebral hemispheres; viviparous; uterine gestation.

Subclass I. Ornithodelphia.—Order Monotremata.—Urinary and genital outlets opening into the cloaca. (Echidna, Ornithorhynchus.)

Subclass II. Didelphia.—Order Marsupialia.—Mammals with a marsupium and bones supporting it. (Macropus, Didelphys.)

Subclass III. Monodephia.—Placental mammals.

Super-order I. Ineducabilia.—Brain with a relatively small, smooth cerebrum.

Order 1. *Bruta.*—Incisors absent; sometimes toothless. (*Bradypus.*)

Order 2. *Glires.*—Rodents, incisors large. (Sciurus.)

Order 3. *Insectivora.*—Fore limbs often peculiarly adapted for burrowing; molars with conical cusps. (Scalops.)

Order 4. *Chiroptera.*—Fore limbs adapted for flight. (Vespertilio.)

Super-order II. Educabilia.—Brain with a relatively large, convoluted cerebrum.

Order 5. *Cete.*—Cetaceans; fish-like in form, no hind limbs. (Balæna.)

Order 6. *Sirenia.*—Fish-like in form, but with ascending rami to the lower jaw; teeth ruminant-like. (Manatus.)

Order 7. *Proboscidea.*—Snout prolonged into a proboscis. (Elephas.)

Order 8. *Hyracoidea.*—Long curved incisors; feet with pads; toes encased in hoofs. (Hyrax.)

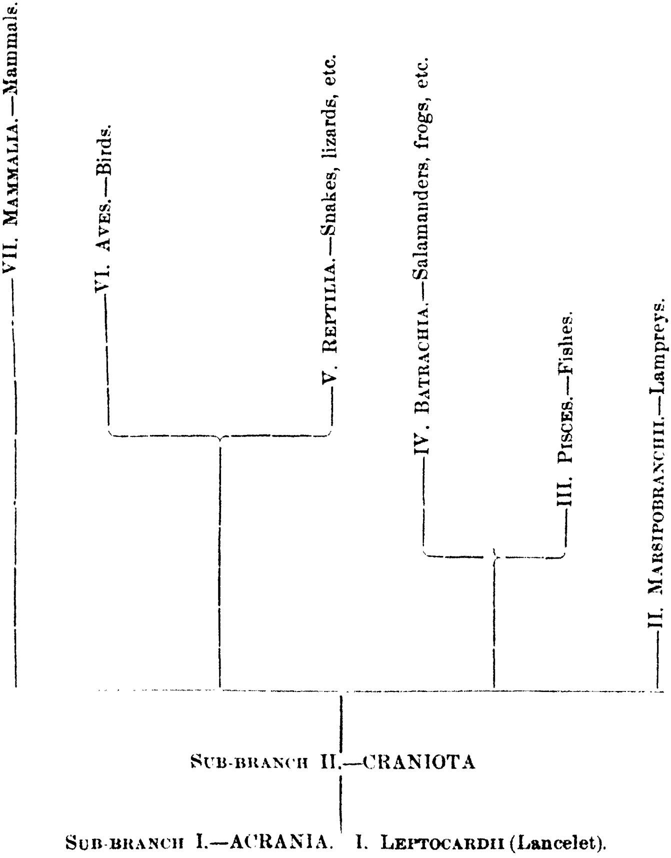
Order 9. *Toxodontia.*—Extinct forms, with well developed incisors. (Toxodon.)

Order 10. *Ungulata.*—Ungulates; toes encased in hoofs. (Equus, Bos.)

Order 11. *Carnivora.*—Teeth pointed; claws large. (Felis, Canis.)

Order 12. *Primates.*—Brain with cerebrum nearly or quite covering the cerebellum; nails usually present; body quadrupedal, quadrumanous, or erect and bimanous. (Cebus, Gorilla, Homo.)

Laboratory Work.—All the craniate vertebrates may be dissected in the same general manner, either under water in pans, or, if large, upon the dissecting table. The necessary tools are a scalpel, forceps, scissors, and tenaculum or hook for suspending the specimens or portions of large subjects for better facility in dissecting. A small sharp-pointed narrow-bladed scalpel, besides a large one, curved, as well as sharp-pointed scissors are useful, with a German silver blow-pipe for temporarily distending vessels; and also a blunt-pointed copper wire or probe made for surgeon's use, will be necessary. All these instruments, put up in a compact box, can be purchased at the surgical-instrument maker's, as well as syringes for injecting the circulatory organs and vascular parts of the viscera.



TABULAR VIEW OF THE SEVEN CLASSES OF VERTEBRATES.

VII. MAMMALIA.—Mammals.
VI. AVES.—Birds.
V. REPTILIA.—Snakes, lizards, etc.
IV. BATRACHIA.—Salamanders, frogs, etc.
III. PISCES.—Fishes.
II. MARSIPOBRANCHII.—Lampreys.
SUB-BRANCH II.—CRANIOTA
SUB-BRANCH I.—ACRANIA. I. LEPTOCARDII (Lancelet).

CHAPTER IX.

COMPARATIVE ANATOMY OF ORGANS.

HAVING studied the morphology of animals in a systematic way, it will be well for the student to make a brief review of those facts stated in the foregoing chapters bearing on the origin and successive degrees of complication of the most important organs.

Organs of Digestion—The Mouth and Teeth.—The most important organs in the animal system are those relating to digestion, as an animal may respire solely through its body-walls, or do without a circulatory or nervous system, but must eat in order to live and grow. The opening by which the food is taken into the alimentary canal is called the mouth, whether reference is made to the "mouth" of a hydra or of a vertebrate; although the structure of the edges may differ radically, still in all *Metazoa* the mouth is due to an inpushing of the ectoderm, however differently the edge of the mouth may be supported and elaborated. The edges of the mouth are usually called the lips, but true lips for the first time appear in the Mammalia. The trituration or mastication of the food is accomplished among the invertebrates in a variety of ways, and by organs not always truly homologous.

Hard bodies serving as teeth occur for the first time in the animal series in the sea-urchins, where a definite set of calcareous dental processes or teeth (Figs. 78 and 79), with solid supports and a complicated muscular apparatus, serves for the comminution of the food, which consists of decaying animals and sea-weeds. In those Echinoderms which do not have a solid framework of teeth, the food consists of minute forms of life, protozoans and higher soft-bodied animals, *Among the worms true organs of mastication for the first time appear in the Rotatoria (Fig. 122), where the food, such as infusoria, etc., is crushed and is partly comminuted by the well-marked horny or chitinous pieces attached to the mastax. In most other low worms the mouth is unarmed.* In the leeches there are three, usually in the annelids two, denticulated or serrate, chitinous flattened bodies situated in the extensible pharynx of these worms, and suited for seizing and crushing their prey.

In the higher mollusks, such as the snails (*Cephalophora*) and cuttles, besides broad thin pharyngeal teeth, comparable with those mentioned as existing in the worms, is the lingual ribbon already described (p. 276, Fig. 215), and admirably adapted for sawing or slicing sea-weeds and cutting and boring into hard shells, acting somewhat like a lapidary's wheel ; this organ, however, is limited in its action, and in the cuttles the jaws, which are like a parrot's beak, do the work of tearing and biting the animals serving as food, which are seized and held in place by the suckered arms.

In the crustaceans and insects we have an approach to true jaws, but here they work laterally, not up and down or vertically, as in the vertebrate jaws ; the mandibles of these animals are modified feet, and the teeth on their edges are simply irregularities or sharp processes adapting the mandibles for tearing and comminuting the food. It is generally stated that the numerous teeth lining the crop of crustacea and insects (Fig. 282) serve to further comminute the food after being partially crushed by the mandibles, but it is now supposed that these numerous points also act collectively as a strainer to keep the larger particles of food from passing into the chyle-stomach until finely crushed.

The king-crab burrows in the mud for worms (Nereids, etc.) ; these may be found almost entire in the intestine, having only been torn here and there and partly crushed by the spines of the base of the foot-jaws, which thus serve the purpose effected by the serrated edges of the mandibles of the genuine Crustacea and insects.

Among vertebrates, the lancelet is no better off than the majority of the Cœlenterates and worms, having no solid parts for mastication; and we have seen that the jaws and teeth of the hag-fish and even the lamprey eel form a very different apparatus from the jaws and its skeleton in the higher vertebrates; and that, even in the latter, the bony elements differ essentially in form in the different classes, though originating in the same manner in embryonic life. In the birds we have seen that the mandible and maxilla are encased in horny plates, that true teeth are remarkably exceptionable, the gizzard being, however, provided with two hard grinding surfaces; on the other hand, mammals without teeth are exceptionable.

The teeth of fishes are developed, not only in the jaws, but on the different bones projecting from the sides and roof of the mouth, and extend into the throat. In many cases, in the bony fishes, these sharp recurved teeth serve to prevent the prey, such as smaller fish, from slipping out of the mouth. On the other hand, the upper and lower sides of the mouth of certain rays (*Myliobatis*) are like the solid pavement of a street, and act as an upper and nether millstone to crush solid shells.

In the toothless ant-eaters the food consists of insects, which are swallowed without being crushed in the mouth; true teeth in the duckbill are wanting, their place being taken by the horny processes of the jaws, while in Steller's manatee the toothless jaws are provided with horny solid plates for crushing the leaves of aquatic succulent plants. Examples of the most highly differentiated teeth in vertebrates are seen in those animals, like the bear, whose food is omnivorous, consisting of flesh, insects, and berries, where the crown of the molars are tuberculate; while the canines are adapted for holding the prey firmly as well as for tearing the flesh, and the incisors, for both cutting and tearing the food.

The simplest form of a genuine digestive or enteric canal is to be found in the Hydra, and in a more advanced stage in the marine Hydroids. For the technical name of the digestive tract we may adopt Haeckel's term *enteron.* In the jelly-fishes the stomach opens into four or more water-vascular canals or passages, by which the food, when partially digested and mixed with sea-water, thus forming a rude sort of blood, supplies the tissues with nourishment. In the sea-anemones and coral polyps, the digestive cavity is still more specialized, and its walls are partly separated from the walls of the body, though at the posterior end the stomach opens directly into the body-cavity. In the Echinoderms and worms do we find for the first time a genuine digestive tube, lying in the *perivisceral space* (which, with Haeckel, we may call the *cœlum*), and opening externally for the rejection of waste matter.

In the worms the digestive canal now becomes separated into a mouth, an œsophagus, with salivary glands opening into the mouth, and there is a division of the digestive tract into three regions—*i.e.*, fore (œsophagus), middle (chyle-stomach), and hind (intestine) enteron. In the mollusks and higher worms there is a well-marked sac-like stomach and an intestine, with a liver, present in certain worms (in the ascidians and mollusks), opening into the beginning of the intestine. All these divisions of the digestive tract exist still more clearly in the crustacea and most insects. In the latter, six or more excretory tubes (Malpighian vessels) discharge their contents into the intestines, and in the "respiratory tree" of the Holothurian and the excretory vessels of certain worms we have organs with probably similar uses.

In the vertebrates, from the lancelet to man, the alimentary canal has, without exception, the three divisions of œsophagus, stomach, and intestine, with a liver. In this branch the lungs are either, as in the lancelet, modified parts of the first division of the digestive tract or originally sac-like dilatations of the digestive tract. The intestine is also subdivided in the mammals into the small and large intestine and rectum, a cœcum being situated at the limits between the small and large intestine. We thus observe a gradual advance in the degree of specialization of the digestive organs corresponding to the degree of complication of the animal.

Organs of Circulation.—Intimately associated with the digestive canal are the vessels in which the products of digestion mix with the blood and supply nourishment for the tissues, or, in other words, for the growth of the body. In the Infusoria the evident use of the contractile vesicles is to aid in the diffusion of the partly digested food of these microscopic forms. In the Hydra the food-stuff is directly taken up by the cells lining the cœlum, while the imperfectly formed blood also finds access to the hollows of the tentacles. The mode in which the cells lining the canals in the sponge take up, by means of the large cilia, microscopic particles of food, directly absorbing them in their substance, is an interesting example of the mode of nourishment of cellular tissues of the lower animals.

The sea-anemone presents a step in advance in organs of circulation ; here the partly digested food escapes through the open end of the stomach into the perivisceral chambers, the action of the cilia, with the contractions of the body, churning the blood, consisting of sea-water and the particles of digested food, and a few blood-corpuscles, hither and thither, and forcing it into every interstice of the body, even into the tentacles, so that the tissues are everywhere supplied with food.

The water-vascular system of the Cœlenterates presents an additional step in degree of complexity ; but it is not until we reach the Echinoderms on the one hand, and such worms as the *Nemertes* and allies on the other, where definite tubes or canals, the larger ones contractile, and in the latter type at least formed from the mesoderm, serve to convey a true blood to the various parts of the body, that we have a definite blood system. In the Echinoderms a true hæmal or vascular system may co-exist with the water-vascular system. In the annelids, such as the *Nereis*, one of the blood-vessels may be modified to form a pulsating tube or "heart," by which the blood is directly forced outward to the periphery of the body through vessels which may, by courtesy, be called *arteries*, while the blood returns to the "heart" by so-called veins.

The mollusks have a circulatory system which presents a nearer approach to the vertebrate heart and its vessels than even the crustaceans and insects, for the ventricle and one or two auricles, with the complicated arterial and venous system of vessels of the clam, snail, and cuttle-fish, truly foreshadow the genuine heart and systemic and pulmonary circulation of the vertebrates. The mollusks, and king-crab, and the lobster present some approach to the capillaries of vertebrates. The circulation in certain worms, from *Nemertes* upward, may be said to be *closed*, the vessels being continuous ; but they are not so in insects, where true veins are not to be found, the blood returning to the heart in channels or *lacunæ* in the spaces between the muscles and viscera.

We have seen that in vertebrates the "aortic heart" of the lancelet or *Amphioxus* is simply a pulsating tube, and there are portions of other vessels which are pulsatile, so that there is, as in some worms, a system of "hearts." A genuine heart, consisting of an auricle and a ventricle only, first appears in the lamprey. This condition of things survives in fishes, with the exception of those forms, such as the lung-fish (*Dipnoans*), whose heart anticipates in structure that of the amphibians and reptiles, in which a second auricle appears. Again, certain reptiles, such as the crocodiles, anticipate the birds and mammals in having two ventricles—*i.e.*, a four-chambered heart. It should be borne in mind that in early life the heart of all skulled vertebrates (*Craniota*) is a simple tube, and as Gegenbaur states, "as it gradually gets longer than the space set apart for it, it is arranged in an S-shaped loop, and so takes on the form which the heart has later on." Owing to this change of form, it is divided into two parts, the auricle and ventricle.

A striking feature first encountered in the craniate vertebrates is the presence of a set of vessels conveying the nutrient fluid or chyle which filters through the walls of the digestive canal to the blood-vessels ; these are the *lymphatics*. In the lancelet, as well as in the invertebrate animals, such vessels do not occur, but the chyle oozes through the stomach-walls and directly mixes with the blood.

Organs of Respiration.—Always in intimate relation with the circulatory system are the means of respiration. The process may be carried on all over the body in the simple animals, such as Protozoa or sponges, or, as in Cœlenterates, it may be carried on in the water-vascular tubes of those animals, while in the so-called "respiratory tree" of Echinoderms it may go on in company with the performance of other functions by the same vessels. Respiration, however, is inclined to be more active in such finely subdivided parts of the body as the tentacles of polyps, of worms, or any filamentous subdivisions of any of the invertebrates; these parts, usually called gills, though only the gills of fishes are truly such, present in the aggregate a broad respiratory surface. Into the hollows of these filamentous processes, which are usually extensions of the body-walls, blood is driven through vessels, and the oxygen in the water bathing the gills filters through the integument, and immediately gains access to and mixes with the blood.

The gills of the lower animals appear at first sight as if distributed over the body in a wanton manner, appearing in some species on the head, in others along the sides of the body, or in others on the tail alone; but in fact they always arise in such situations as are best adapted to the mode of life of the creature.

The gills of many of the lower animals afford an admirable instance of the economy of nature. The tentacles of polyps, polyzoans, brachiopods, and many true worms serve also, as delicate tactile organs, for grasping and conveying food to the mouth, and often for locomotion. The suckers or "feet" of star-fish or sea-urchins also without doubt perform the office of gills, for the luxuriously branched, beautifully-colored tentacles of the sea-cucumber are simply modifications of the ambulacral feet. One of the readiest ways of judging of the mental condition, so to speak, of a worm, such as *Sabella* or *Terebrella* or of a polyzoon or a brachiopod, is to watch the movements of their beautiful delicate gills, which are thrust in or out, waved back and forth, slowly or suddenly, according to the degree of tranquillity or disquietude of their possessors.

In the mollusks, especially the snails and cuttle-fish, the gills are in close relations with the heart, so that in the cuttle-fish the auricles are called "branchial hearts." The gills of crustaceans (Fig. 259) are attached either to the thoracic legs or are modified abdominal feet, being broad, thin, leaf-like processes, into which the blood is forced by the contractions of the tubular heart. Respiration in the insects goes on all over the interior of the body, the tracheal tubes distributing the air so that the blood becomes oxygenated in every part of the body, including the ends of all the appendages. The gills of aquatic insects are in all cases filamentous or leaf-like expansions of the skin permeated by tracheæ (Fig. 326); they are, therefore, not strictly homologous with the gills of crustaceans or of worms.

The gills of fishes are so situated as to be constantly bathed by fresh water; in the amphibians and lung-fishes, lungs, which are outgrowths of the enteric canal, replace the air-sacs of the fishes, the air being now swallowed by the mouth and gaining access by a special duct, the larynx, to highly specialized organs of respiration, the lungs, which are situated in the thoracic cavity near the heart.

The Nervous System.—We have seen that animals of comparatively complicated structure perform their work in the animal economy without any nervous system whatever. It has been only recently discovered that in a few jelly-fish is there, for the first time in the animal series, a consecutive nervous system, with definite nerve-centres or ganglia. In most Acalephs none has been found, so that the majority of Cœlenterates perform their complicated movements, swimming about for food, taking it in, digesting it, and reproducing their kind, without the aid of what seems, when we study vertebrates alone, as the most important and fundamental system of organs in the body.

The Protozoa, sponges, and most Cœlenterates depend, for the power of motion, on the contractility of the protoplasm of the body, whether or not separated into muscular tissue. In the Hydra for the first time appear the traces of a nervous tissue in the so-called nervo-muscular cells, one portion of a cell being muscular, the other nervous in its functions.

A more definite nervous organization is the disconnected bodies and rod-like nerve-cells, and other nervous bodies found near the eye-spots, and the nerve-cells and fibres at the base of the sea-anemone ; but, as has been stated, a genuine nervous system for the first time appears in certain naked-eyed jelly-fishes, in which it is circular, sharing the radiated disposition of parts in these animals. The Echinoderms have a well-developed nervous system, consisting of a ring (without, however, definite ganglia, though masses of ganglionic cells are situated in the larger nerves), surrounding the œsophagus, and sending a nerve into each arm ; or in the Holothurians situated under the longitudinal muscles radiating from that muscle closing the mouth.

In all other invertebrate animals, from the worms and mollusca to the crustaceans and insects, the nervous system is fundamentally built upon the same plan. There is a pair of ganglia above the œsophagus called the "brain ;" on the under side is usually a second pair ; the four, with the nerves or commissures connecting them, forming a ring. This arrangement of ganglia, often called the "œsophageal ring," constitutes, with the slender nerve-threads leading away from them, the nervous system of the lower worms, in many of which, however, as also in the *Polyzoa* and *Brachiopoda*, the subœsophageal ganglia are wanting. Now to the œsophageal ring with its two pairs of ganglia add a third pair of visceral ganglia, and we have the nervous system of the clam and many mollusks. In the higher ringed worms, the *Annulata*, and in the Crustacea and Insects, a chain of ganglia, or brains, which is ventral, lying on the floor of the cœlum or body-cavity, completes the highest form of nerve-centre found in the invertebrate animals, unless we except the mass of ganglia, partly enclosed in an imperfect cartilaginous capsule of the Cephalopods, which hints at the brain and skull of Vertebrates. The nervous cord of the *Appendicularia*, an Ascidian, is constructed on the same plan as in the Annulata, but the mode of origin and apparently dorsal position of the nervous system of the tailed larval Ascidian presents features which apparently anticipate the state of things existing among the lower vertebrates, such as the lancelet.

In the last-named animal the nervous cord has a dorsal position—*i.e.*, rests above the alimentary canal; but as yet no brain appears, only a very slight enlargement of the anterior end of the nervous cord from which a few nervous threads are distributed to minute sense-organs in the head. In all the craniate Vertebrates, from the lamprey upward, the brain is a series of close-set ganglia, having a definite site, enclosed by a skull or brain-box, and with definite relations to the sense-organs. Attention has already been given in a general way, in the foregoing pages, to the increasing complexity of the brain, especially to the relative size and markings of the cerebral hemispheres and cerebellum, as we rise from the fish to man.

Organs of Sense.—While all animals, perhaps without exception, unless it be the root-barnacles, and a few other parasitic forms, have the sense of touch, which, in the lower *Protozoa* is so slight as to be compared with the contractility common to all living protoplasmic matter, whether existing in cellular tissue or one-celled, independent animals; not all of the lower animals have, however, definite sense-organs.

The Eye.—The most important of these are undoubtedly eyes, as they are the most commonly met with. The simplest form of eyes are perhaps those of the sea-anemone, in which there are, besides pigment cells forming a colored mass, refractive bodies which may break up the rays of light impinging on the pigment spot, so that these creatures may be able to distinguish light from darkness. The next step in advance is where a pigment mass covers a series of refractive cells called "crystalline rods" or "crystalline cones," which are situated at the end of a nerve proceeding from the "brain." Such simple eyes as these, often called "eye-spots," may be observed in the flat worms, and they form the temporary eyes of many larval worms, Echinoderms and mollusks. In some nemertean worms, such as certain species of *Polia* and *Nemertes,* true eyes appear, but in the ringed worm, *Neophanta celox*, Greef describes a remarkably perfect eye, consisting of a projecting spherical lens covered by the skin, behind which is a vitreous body, a layer of pigment separating a layer of rods from the external part of the retina, outside of which is the expansion of the optic nerve. Eyes are also situated on the end of the body in some worms, and in a worm called *Polyophthalmus* each segment of the body bears a pair of eyes.

The eyes of mollusks are, as a rule, highly organized, until in the cuttle-fish the eye becomes nearly as highly developed as in fishes, but still the eye of the cuttle-fish is not homologous with that of Vertebrates, since in the former the crystalline rods are turned toward the opening of the eye, while in Vertebrates they are turned away from the opening of the eye, so that, as Huxley as well as Gegenbaur show, the resemblance between the eye of the Cephalopods and of the Vertebrates is a superficial one.

While, as we have seen, the eyes of the worms and the mollusks are situated arbitrarily, by no means invariably placed in the head, in the Crustaceans the eyes assume in general a definite position in the head, except in a schizopod crustacean (*Euphausia*), where there are eye-like organs on the thorax and abdomen. In insects there are both simple and compound eyes occupying definitely the upper and front part of the head.

The eyes of the lancelet are not homologous with those of the higher Vertebrates, being only minute pigment spots comparable with those of the worms. In the skulled Vertebrates the eyes are of a definite number, and in all the types occupy a definite position in the head.

The Ear.—The simplest kind of auditory organ is to be found in jelly-fishes, where an organ of hearing first occurs. In these animals, situated on the edge of the disk, are minute vesicles containing one or more concretionary bodies or crystals. Reasoning by exclusion, these are supposed to represent the ear-vesicles or *otocysts* of worms and mollusks; and the concretions or crystals, the *otoliths* of the same kind of animals.

The otocysts or simple ears of worms and mollusks are minute and usually difficult to find, especially the auditory nerve leading from them to the nerve-centres. In the clam it is to be looked for in the so-called foot. In the snails the auditory vesicles are placed in the head close to the brain, as also in cuttle-fish. The ears of Crustacea are sacs formed by inpushings of the integument filled with fluid, into which hairs project, and which contain grains of sand which have worked in from the outside, or concretions of lime. These are situated in the shrimps and crabs at the base of the inner antennæ, but in certain other lower Crustacea, as in *Mysis*, they are placed at the base of the lobes of the tail. In the insects the ear is a sac covered by a tympanum, with a ganglionic cell within, leading by a slender nerve-fibre to a nerve-centre, and in these animals the distribution of ears is very arbitrary. In the locust they are situated at the base of the abdomen (Fig. 279); in the green grasshoppers or katydids and the crickets in the fore tibiæ; and it is probable that in the butterflies the antennæ are organs of hearing.

The vertebrate ears are two in number and occupy a distinct, permanent position in the skull, however much modified the middle and outer ear become.

Organs of Smell.—The sense of smell is obscurely indicated by special organs in the invertebrate animals, nasal organs as such being characteristic of the skulled Vertebrates. Whether organs of smell exist in any worms or not is unknown; there are certain pits in some worms which may possibly be adapted for detecting odors. In some insects at least the organs of smell are without doubt well developed; the antennæ of the burying beetles are large and knob-like, and evidently adapted for the detection of carrion. It is possible that certain organs situated at the base of the wings of the flies and on the caudal appendages of the cockroach and certain flies (Fig. 290) are of use in detecting odors.

CHAPTER X.

DEVELOPMENT AND METAMORPHOSES OF ANIMALS.

Embryology.—The development of the individual is often an epitome of the classification of the order or class to which it belongs, as well as of the development or appearance in geological history of the different members of the order or class to which the individual belongs. The changes undergone by the animal within the egg are often so sudden and marked that the separate chapters of its history as an embryo can be read side by side with the history of the succession of the different genera and families of its type in past ages. Moreover, it is now generally supposed by naturalists that these critical periods in the development of the individual have a constant relation to external causes which have acted on the ancestors of the animal, and hence that these changes are the result of influences and changes in the surroundings of the forms which have preceded. So much interest, therefore, attaches to the subject of the early development of animals, that much prominence has in the foregoing pages been given to the matter.

We may now briefly review the more striking phenomena of development in the invertebrate animals, and close with a summary of the mode of development of Vertebrates.

The eggs of all animals consist of three portions, the egg proper, consisting of a mass of protoplasm enveloped by the yolk or food-stuff, the nucleus or germinative vesicle, and the nucleolus or germinative spot.

Before the egg is ready for fertilization it undergoes a special process of maturation, involving the following series of events : 1. Transportation of the germinal vesicle to the surface of the egg ; 2. An absorption of the membrane of the nucleus or germinative vesicle and a change in the germinative spot ; 3. The portion of the nucleus surviving assumes a spindle-shape, this portion being largely formed from the nucleolus ; 4. One end of the spindle enters into a protoplasmic prominence at the surface of the egg ; 5. The spindle divides into two halves, one remaining in the egg, the other in the prominence, the latter separating from the egg and forming the polar cell ; 6. A second polar cell forms in the same manner as the first, part of the spindle still remaining in the egg ; 7. The part of the spindle remaining in the egg, after the formation of the second polar cell, is converted into a nucleus, the female *pronucleus,* and finally, just before fertilization, the female pronucleus takes its position at the centre of the egg.

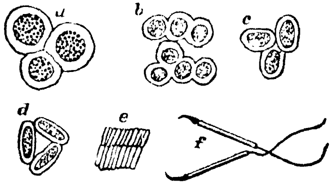


Fig. 539.—Development of the sperm-cells of a blind worm (*Epicrium glutinosum*). *a*, testis-cell; *b*, the same, more numerous ; *c*, *d*, *e*, becoming more numerous and finally forming spermatozoa (*f*). Highly magnified.—After Minot.

After this, the first step in the development of many-celled animals is the fusion of the protoplasm of the female pronucleus with that of the sperm-cell ; for this end the latter is exceedingly minute and provided with a vibratile cilium or "tail," so that it may force its way in toward the centre of the egg. These sperm-cells are developed in the testis of the male. On close examination with very high powers of the microscope, certain cells, called "mother cells," may be found developed in fine tubules forming the gland ; these are known to possess several nuclei, which are destined to become spermatozoa (Fig. 539, *a* and *b*) ; these multiply until they become very numerous, elongated, and packed side by side in bundles (*e*); from each one a cilium or "tail" grows out, when they are set free from the mother-cell. In this tailed form they are very active, and effect the fertilization of the egg of an animal of the same species. This is due to contact of one spermatozoon with the female pronucleus situated in the egg. Immediately after the spermatozoon has penetrated into the egg, its "head" is converted into a nucleus, called the male *pronucleus*; after this, radiating striæ make their appearance around its surface; then the male pronucleus travels toward the female pronucleus, and finally the male and female pronuclei fuse together and form the first "segmentation nucleus."

This nucleus subdivides, and the result is a mass of cells resembling a mulberry, and hence called the *morula*. The outer circle of the cells of the morula may hereafter form what is called the blastoderm; after a while it pushes in at one point, and the portion thus forced is called the inner germ-layer (*endoderm*) and the outer is called the *ectoderm* or outer germ-layer, and in this condition the germ is called a *gastrula*. Subsequently, a third layer develops from the others—just how is not certainly known—and after this the different tissues become developed.

All animals, from sponges to man, become first two- and afterward three-layered sacs; so that all animals above the *Protozoa* not only, as a rule, originate from eggs, but may be said to travel, up to a certain point, the same developmental path. From this point the members of different types of life diverge. How different are the modes of development of animals has been set forth in the different life-histories related in the foregoing pages of this book.* But the laws of growth are as stable and uniform—certain causes producing certain results—as the laws of the motions of the heavenly bodies.

When the workings of these laws of development are interfered with by sudden accidents, by too scanty nourishment, and by the transmission of the effects of such accidents or abnormal products from parents who have been affected by them, the results are usually abnormal, more or less distorted forms, with greater or less defects ; and here again have been observed laws governing the production of abnormalities, the study of these being called *teratology.*

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* For a fuller, more consecutive, though still fragmentary account, the reader is referred to the author's "Outlines of Comparative Embryology, or Life Histories of Animals, including Man."

We may study the mode of development of the domestic fowl or hen as the best known example to illustrate the changes undergone by an embryo vertebrate, for this purpose condensing the statements of Foster and Balfour in their " Elements of Embryology."

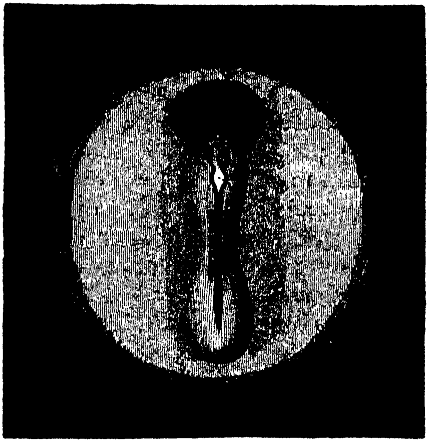

Fig. 540.—Blastodermic disk and germ of a rabbit about one day old, seen from the back. *a*, edge of the head-end of the *amnion; b*, fore-brain; *c*, lateral expansion of the same, or primitive eye-vesicle; *d*, middle, *e*, hind brain. There are eight protovertebræ, between which is situated the spinal cord. Enlarged ten times.—After Bischoff.

First Day.—After fertilization of the egg, segmentation of the egg occurs, but instead of being total, forming a morula or mulberry mass, it is, as in all birds and in the majority of fishes and reptiles (except the lancelet and lamprey eel), partial, or confined to the periphery of the yolk, resulting in the formation of a blastoderm, the oval more apparent portion being called the " blastodermic disk," which is the beginning of the embryo. In six or eight hours after fertilization the three germ-layers appear. From the outer germ-layer are destined to arise the skin and wall of the body with the nervous system; from the second (mesoderm, in the embryo called the mesoblast) are formed the heart and the vascular system, as well as the stomach and intestines.

The middle layer now thickens, causing the mark known as the "primitive streak," along the middle of which runs the "primitive groove." The notochord now appears and the primitive vertebræ (*protovertebræ*, Fig. 540). The *amnion* arises as a membrane, splitting off from the outer germ-layer of the embryo, and finally forms a cavity which is filled with a fluid. About this time the *allantois* arises as an offshoot of the alimentary canal, budding out at the hinder end of the embryo, and finally curving over the embryo, serving as a fœtal respiratory membrane.

Second Day.—The three portions or vesicles of the brain now appear (Fig. 540), as well as the alimentary tract and heart, both arising in the head-fold or enlargement (Fig. 540, *a* to *c*), and soon the blood-vessels arise as channels in which blood-corpuscles appear, originating as amœba-like cells separating from the cellular mass of the mesoderm. During the second day also the eyes and ears begin their development, being at first simply folds or inpushings of the outer germ-layer.

Third Day.—This is one of the most eventful days, as important steps in the elaboration of the different organs are taken; the different parts of the brain, of the alimentary tract and its appendages being sketched out, and the rudiments of the lungs, the liver, pancreas, nose, and different parts of the eye and ear appearing. On the *fourth day* the wings and legs grow out, appearing first as flattened buds. The notochord, which is indicated by the second day, by the sixth begins to diminish in size, disappearing by the time the chick is hatched, while by the twelfth day the deposition of bone in the bodies of the vertebræ commences. Between the eightieth and one hundredth hour the internal differences in the sexes appear, the testes beginning to arise on the sixth day.

Fifth Day.—The limbs have by this time developed so as to show the knee- and elbow-joints, as well as the cartilages

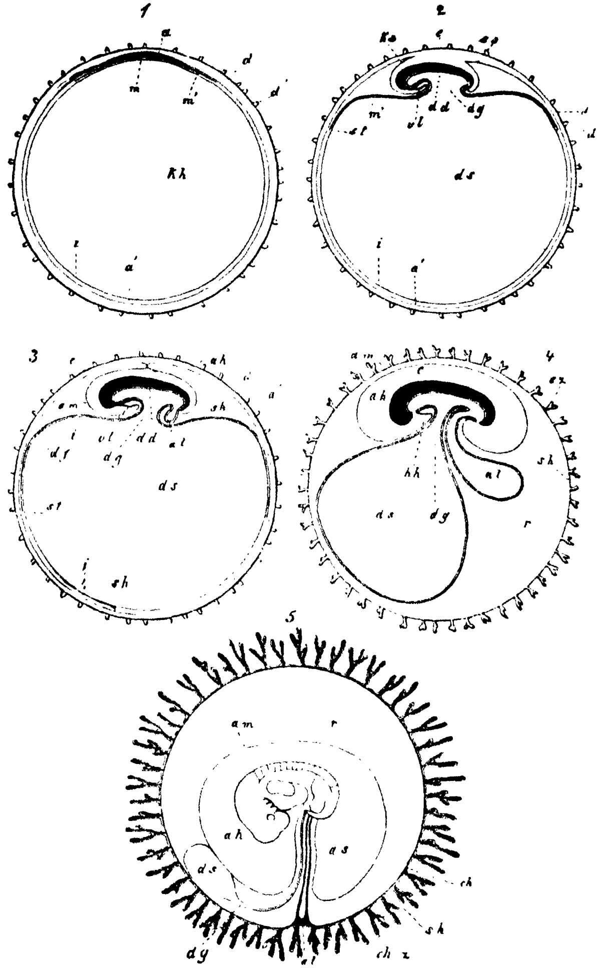

Fig. 541.—Five schematic figures showing the development of the fœtal egg-membranes, where in all except the last the embryo is represented as if seen in longitudinal section. 1. Diagram of egg with *zona pellucida*, blastoderm (*a*, *i*), germinal disk, and) embryo. 2. Egg with the first traces of the yolk-sac (*d*) and amnion (*ks*, *ss*, and *am*. 3. Egg with the amnion uniting and forming a sac; the allantois (*al*) budding out. 4. Egg with the villi of the serous membrane (*sz*); the allantois larger; embryo with mouth and anal opening. 5. Egg in which the vascular layer of the allantois lies close to the serous layer and has grown into the villi of the same, constituting the true chorion (*ch*). Yolk-sac much smaller, about to be drawn into the cavity of the amnion,

which precede the formation of the bones of the digits and limbs. The primitive skull also arises from the mesoderm.

Until the sixth day it would be impossible to say whether the embryo was that of a bird, reptile, or mammal, but now the characters peculiar to birds appear. The wings and legs manifest their bird-like characters, the crop and intestinal cœca are indicated, " the stomach takes the form of a gizzard, and the nose begins to develop into a beak, while the incipient bones of the skull arrange themselves after the avian type. . . . From the eleventh day onward, the embryo successively puts on characters which are not only avian, but even distinctive of the genus, species, and variety " (Balfour). By the ninth or tenth day the feathers originate in sacs in the skin, while the nails and scales begin to appear on the thirteenth day, and at this time the various muscles of the body can be distinguished. Development is thus seen to be from the general to the special, from the simple to the complex ; the trunk is first indicated ; while the peripheral parts—*i.e.*, the extremities, the digits, the skin, feathers or scales, or hair, whatever be the type of Vertebrate—are the last to be elaborated ; in other words, the characters of the branch, class, and orders are the first to be evolved, those of the family, genus, and species the last.

The development of the rabbit, guinea-pig, or any mammal, including even man, follows much the same order as in the chick, there being, however, a well-marked morula ; the differences are due to the fact that the embryo mammal

d, yolk-skin ; *d′*, villi of the yolk-skin ; *sh*, serous membrane ; *sz*, villi of the serous membrane ; *ch*, chorion (vascular layer of the allantois); *chz*, true villi of the chorion (arising from the projections of the chorion and the sac of the serous membrane); *am*, amnion ; *ks*, head-fold of the amnion ; *ss*, tail-fold of the amnion ; *ah*, cavity of the amnion ; *as*, sheath of the amnion for the navel-string ; *a*, the first beginning of the embryo arising from a thickening of the outer layer of the blastoderm *a′* ; *m*, thickening forming the germ in the middle layer of the blastoderm (*m′*), which at first only reached as far as the germinal disk, and afterward forms the vascular layer of the yolk-sac (*df*) which connects with the intestino-muscular layer (darmfaserblatt); *st*, *sinus terminalis* ; *dd*, intestino-glandular layer (darmdrusenblatt) arising out of a part of *i*, the inner layer of the blastoderm (afterward the epithelium of the yolk-sac) ; ***kh***, cavity of the blastoderm, which afterward becomes (*ds*) the cavity of the yolk-sac ; *dg*, passage way of the yolk ; *al*, allantois ; *e*, embryo ; *r*, original space between the amnion and chorion, filled with albuminous fluid ; *vl*, anterior body-wall in the region of the heart ; *hh*, cavity of the heart without the heart itself. In Figs. 2 and 3, the amnion is, for the sake of clearness, represented as situated too far away from the embryo ; so also the cavity of the heart is drawn too small and the embryo too large, since, except in Fig. 5, they are only drawn diagrammatically.—From Kolliker's " Entwickelungsgeschichte des Menschen und der höheren Thiere."

develops in a specialized portion of the oviducts, the uterus or womb, and that the growing germ until birth is supplied not with yolk as food, but by the nourishment in the maternal blood. In fact, while the eggs of reptiles and birds are enormous, it was not known with certainty until 1827 that mammals developed from eggs. The eggs of these animals are very minute, owing in part to the minute amount of yolk they contain ; that of man being less than a quarter of a millimetre ($\frac{1}{120}$ inch) in diameter.

The mammalian embryo, nourished as it is through the maternal circulation, needs additional temporary organs ; these are the *chorion* (Fig. 541, *ch*), formed from the vitelline membrane (present in birds as well as mammals), which sends off *villi* or processes extending into the walls of the womb. Besides this, in the higher or placental mammals, the placenta or after-birth is formed, which serves as an organ of respiration as well as to supply the embryo or fœtus with nourishment, and to carry off its effete products by means of the maternal circulation.

It is comparatively late in embryonic life that the mammalian features appear ; in the dog it is twenty-five days before it can be told whether the embryo is a mammal or not.

All mammals may be said to pass through a morula and gastrula stage. In the next stage when the nervous chord and notochord arise, the mammalian germ is on the same footing with an Ascidian larva. In a succeeding stage, when the protovertebræ appear, an Amphioxus stage is reached ; when a brain is formed, the level of the fishes is reached ; after the limbs bud out the young mammals may be said to assume the condition common to the embryos of all Amphibian and higher Vertebrates. When the allantois begins to appear the amphibian feature (the want of an allantois) is dropped. When the placenta has developed the avian characters are surpassed and the mammalian features assumed. Thus the development of the individual mammal is an epitome of that of the branch or type to which it belongs, and the successive steps in the degree of specialization of the individual mammal are also paralleled by the geological succession of the representatives of the different classes, as without much doubt lancelets (or at least acraniate, boneless forms) were the first Vertebrates to appear, and we know that fishes appeared before Amphibians, that their type culminated before the reptiles held full sway in Mesozoic times, and that birds, after them mammals, and, last of all, man appeared, who crowns the series of vertebrate forms.

Metamorphosis.—While many animals are hatched like the chick with the form of the parent, others pass through a series of changes of form called *metamorphoses* ; these changes of form adapt the animal to changes in its surroundings, involving alterations in its mode of life—slight if the change of body-form is slight, thorough-going and radical if its body becomes profoundly modified. As an example of a complete metamorphosis may be cited the life-histories of the jelly-fishes, the star-fish, sea-urchins, sea-cucumbers, the marine-worms, the mollusks, the crustaceans, insects, and the salamanders and toads and frogs, already described in the foregoing pages. If the student will read and compare these different accounts, and then consider the striking differences between the complicated histories of certain species, compared with the direct mode of growth of other species of the same order or family, or even of the same genus, the inquiry will arise, What is the purpose or use of such a series of changes? If he look carefully into the embryological changes of those species which are born or hatched with the form of the adult, he will see that their embryological history is, in point of fact, a condensed summary of the changes undergone after hatching by their co-species, which, to gain the same adult form, have been subjected by nature to a series of complicated, and, at first sight, superfluous changes of form and environment.

Most shrimps and crabs undergo a complicated metamorphosis ; in the different changes of forms they lead different lives, and are subjected to different surroundings, the larvæ, for the most part, being free-swimming and living near the surface of the water, while the parents are stationary. The barnacle, when very young, swims near the surface of the sea, afterward, as a pupa, becoming fixed to a rock ; the young oyster-spat swims freely about, finally becoming fixed to the bottom. This change of life and of form undoubtedly tends to prevent the extinction of the species, since, if at a given moment the parents were swept out of existence, the young living in a different station would continue to represent the species. This law is seen to hold good among insects, where many species are represented in the winter-time by the egg alone, others by the caterpillars, others by the chrysalis, while still others hybernate as imagines. Again, in the marine species, the free-swimming young are borne about by ocean and tidal currents, and in this way what in adult life are the most sedentary forms become widely distributed from coast to coast and sea to sea. On the other hand, the larval forms of fixed marine animals serve as food for fishes, especially young fishes and numerous invertebrates, while their stationary parents afford subsistence for still other forms of life ; thus were it not for the metamorphoses of animals, many species would become extinct sooner than they do, while the great overplus of larval forms gives to many other species of animals a hold on existence.

Metamorphosis among the invertebrate animals, especially, is perhaps the rule and not the exception. Where animals develop directly, as in certain insects, crustaceans, certain salamanders, toads and frogs, this is due to some change in the environment ; in the case of Amphibians, perhaps the want of water, or some other cause, there always being an adaptation in the case of the direct mode of development to the surroundings of the animal and the requirements of its existence.

Parthenogenesis, and Alternation of Generations.—Having traced the normal process of development of animals, we may turn to certain unusual or abnormal modes of production. As an example of what is known as "alternation of generations," may be cited the mode of development of the jelly-fish, such as the naked-eyed medusæ (*Melicertum* and *Campanularia*), which at one time of life develop by budding, at another by eggs ; of the trematode worms, the adult forms of which lay eggs, while the *redia* or *proscolex* of the same worm produces *cercariæ* by internal budding. Here also may be cited the cases of strobilation of the Aurelia, the tape-worm, the Nais, Syllis, and Autolycus, among Annelids. Thus among Cœlenterates and worms, as well as some Crustacea, a large number of individuals are produced, not from eggs, but by budding.

Similar occurrences take place among insects, as the Aphis or plant-louse, in which a virgin *Aphis* may bring forth in one season nine or ten generations of Aphides, so that one *Aphis* may become the parent of millions of young. These young directly develop from eggs or buds which are never fertilized, hence the term *parthenogenesis*, or virgin-reproduction, sometimes called *agamogenesis* (or birth without marriage). The bark-lice as well as the Aphides develop in this manner during the warm weather; but at the approach of cold both male and female Aphides and Coccidæ appear, the females laying fertilized eggs, the first spring brood thus being produced in the normal, usual manner.

Still more like the production of young in the redia of the Trematode worms is the case of the larva of a small gall-gnat (*Miastor*), which during the colder part of the year from autumn to spring produces a series of successive generations of larvæ like itself, until in June the last brood develops into sexually mature flies, which lay fertilized eggs.

While the larval Miaster produces young like itself, the pupa of another fly, *Chironomus*, also lays unfertilized eggs.

A number of moths, including the silk-worm moth, are known to lay unfertilized eggs which produce caterpillars. Among the *Hymenoptera*, the currant saw-fly, certain gall-flies, several species of ants, wasps (*Polistes*), and the honey-bee, are known to produce fertile young from unfertilized eggs; in the case of the ants and bees, the workers lay eggs which result in the production of males, while the fertilized eggs laid by the female ant or queen bee produce females or workers.

Taking all these cases together, *parthenogenesis* is seen to be due to budding, or cell-division, or multiplication. Now, it will be remembered that the egg develops into an animal by cell-division, so that fundamentally parthenogenesis is due to cell-division, the fundamental mode of growth; hence, normal growth and parthenogenesis are but extremes of a single series. In this connection, it will be remembered that all the *Protozoa* reproduce by simple cell-division, that among them the sexes are not differentiated, that they do not reproduce by fertilized eggs; hence, so to speak, among *Protozoa* parthenogenesis is the normal mode of reproduction; and when it exists in higher animals it may possibly be a survival of the usual protozoan means of stocking the world with unicellular organisms, with which we know the waters teem. And this leads us to the teleology or explanation of the cause why parthenogenesis has survived here and there in the world of lower organizations; it is plainly, when we look at the millions of Aphides, of bark-lice, the hundreds of thousands inmates of ant-hills and bee-hives, for the purpose of bringing immediately into existence great numbers of individuals, thus ensuring the success in life of certain species exposed to great vicissitudes in the struggle for existence. That this unusual mode of reproduction is all-important for the maintenance of the existence of most of the parasitic worms, is abundantly proved when we consider the strange events which make up the sum total of a fluke or tape-worm's biography. Without this faculty of the comparatively sudden production of large numbers of young by other than the slow, limited process of ovulation, the species would be stricken off the roll of animal life.

Dimorphism and Polymorphism.—Involving the production of young among many-celled animals (*Metazoa*) by what is fundamentally a budding process, we have two sorts of individuals. When the organism is high or specialized enough to lay eggs which must be fertilized, we have a differentiation of the animal into two sexes, male and female. Reproduction by budding involves the differentiation of the animal form into three kinds of individuals—*i.e.*, males, females, and asexual individuals, among insects often called workers or neuters. These have usually, as in ants and bees, a distinct form so as to be readily recognized at first sight. Among the Cœlenterates and worms the forms reproducing by parthenogenesis are usually larval or immature, as if they were prematurely hurried into existence, and their reproductive organs had been elaborated in advance of other systems of organs, for the hasty, sudden production, so to speak, of large numbers of individuals like themselves.

In insects, as we have stated elsewhere,* dimorphism is intimately connected with agamic reproduction. Thus the summer wingless, asexual Aphis and the perfect winged autumnal Aphis may be called dimorphic forms. The perfect female may assume two forms, so much so as to be mistaken for two distinct species. Thus, an oak gall-fly (*Cynips quercus-spongifica*) occurs in male and female broods in the spring, while the autumnal brood of females were described originally as a separate species under the name *C. aciculata.* Walsh considered the two sets of females as dimorphic forms, and that *Cynips aciculata* lays eggs which produce *C. quercus spongifica.* Among butterflies, dimorphism occurs. *Papilio memnon* has two kinds of females, one being tailless, like the tailless male, while *Papilio Pammon* is polymorphic, there being three kinds of females besides the male.

There are also four forms of *Papilio Ajax*, the three others being originally described as distinct species under the name of *P. Marcellus*, *P. Telamonides*, and *P. Walshii.* Our *Papilio glaucus* is now known to be a dark, dimorphic, climatic form of the common *Papilio Turnus.* There are dimorphic males among certain beetles, as in the *Golofa hastata* Dejean, of Mexico, in which one set of males are large and have a very large erect horn on the prothorax, and in the other the body is much smaller, with a very short conical horn.

Temperature is also associated with the production of polymorphic forms in the temperate regions of the earth, as seen in certain butterflies, southern forms being varieties

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* Guide to the Study of Insects, sixth edition, p. 52

of northern forms, and alpine "species" proving to be varieties or seasonal forms of lowland species. For example, Weismann states that the European butterflies, *Lycaon amyntas* and *polysperchon*, are respectively summer and spring broods. *Anthocharis Simplonica* is an alpine winter form of *Anthocharis Belia*, as is *Pieris bryoniæ* of *Pieris napi.* In this country, as Edwards has shown, two of the polymorphic forms of *Papilio Ajax—i.e.*, *Walshii* and *Telamonides*—come from winter chrysalids, and *P. marcellus* from a second brood of summer chrysalids. It thus appears that polymorphism is intimately connected with the origin of species. Perhaps the most remarkable case of polymorphism is to be seen in the white ants (*Termites*), where in one genus there are two sorts of workers, two sorts of soldiers, and two kinds of males and females, making eight sorts of individuals ; in the other genera there are six. Among true ants there are, besides the ordinary males, females, and workers, large-headed workers. In the honey-ant (*Myrmecocystus Mexicanus*), besides the usual workers, there are those with enormous abdomens filled with honey. Other insects, especially certain grasshoppers, are dimorphic. Certain parasitic Nematode worms are dimorphic ; and among the Cœlenterates, especially the Hydroids, there is a strong tendency to polymorphism.

Individuality.—Perfect individuality among animals is the rule, each individual being capable of maintaining an independent existence ; but we have seen that there are many of the lower animals in which it is difficult to determine whether the different members of a colony are really individuals or simply individualized organs.

The student, in referring back to the account of the Portuguese man-of-war, will find it difficult to say whether the four kinds of members of the floating colony are organs or individuals, and he will probably agree with the view that it is best to provisionally call them *zooids* or individualized organs ; for the feeders, the reproductive zooids, the digestive zooids, and the swimming float, or the swimming bells of the other Siphonophores, are highly specialized organs, and only differ from true individuals in lacking the power of free motion and of maintaining an independent existence. So with many other Cœlenterates and with the tapeworm, whose proglottides or segments are finally capable of separate existence. Among the higher invertebrates, even the different members of a colony of white or true ants lack a certain amount of individuality, the workers performing labors upon which the maintenance of the very existence of the colony depends, so that there are different grades of individuality, from examples like the *Hydractinia* and the Siphonophores up to those insects which live socially; and we see that the most perfect individuality exists in those animals which can most efficiently provide for their own sustenance and for the continuance of their species.

Hybridity.—It is rare that two species, even of the same genus, can produce offspring; when such cases occur, the result is called a hybrid. For example, the mule is a hybrid, being bred from a female horse and an ass; but the mule is not fertile, and hybrids are very rarely fertile. The Indian dog and coyote are said by Coues to interbreed, and on the Upper Missouri we have seen dogs which had every appearance of being such hybrids. Dogs also cross with the fox (Darwin). The American bison is known to breed with the domestic cattle, and it seems to be a well-established fact that the hybrids are fertile. Fish readily hybridize.

Darwin states that he knows of no thoroughly well-authenticated cases of perfectly fertile hybrid animals, though he adds, "I have reason to believe that the hybrids from *Cervulus vaginalis* and *Reevesii* and from *Phasianus colchicus* with *P. torquatus* are perfectly fertile." The hare and rabbit are supposed to have fertile offspring; the hybrids of the common and Chinese geese (*Anser cygnoides*) are fertile. The crossed offspring from the Indian humped and common cattle interbreed. Caton has hybridized the Virginia deer with the Ceylon deer and the Acapulco deer; "the hybrids seem perfectly healthy and prolific." Among insects over 100 cases of hybridity have occurred, but it is not known whether the offspring are fertile.

CHAPTER XI.

THE GEOGRAPHICAL DISTRIBUTION OF ANIMALS.

THE assemblage of animal life peopling any one locality or area is called its *fauna*, as the plants of a place constitute its flora. Where the physical geography—*i.e.*, the contour of the surface, the plains, valleys, and hills—is of identical character and the climate the same, the fauna is much the same, but when these characteristics of soil and climate change, as in passing from lowlands to highlands, or from south to north, the assemblage of animals will be found to change in a corresponding ratio. And as there are no definite limits to any large area of the earth's surface, the physical features of one area merging insensibly, as a rule, into adjoining districts, so adjoining faunæ merge into one another, and a certain proportion of the species may range through two or more faunal areas.

There are in nature causes tending to restrain animals within their faunal limits, and others tending to diffuse them, or to cause them to migrate from their specific centres or centres of creation—namely, the point where the individuals of a species are most abundant, and where, accordingly, they are supposed to have originated.

Barriers to the Spread of Animals from their Specific Centres.—Among the most important are the oceans and their basins. The animals of the opposite sides of the Pacific Ocean are entirely unlike, no species being common to the two sides ; while, of the immense numbers of animals peopling the coast of Brazil and the opposite coast of Africa, only two or three are known to be identical. Difference in climate is also a great barrier, the animals of the tropics, as a whole, being unlike those of the temperate zones; while arctic and antarctic animals have features in common. Mountains serve as most important barriers, restraining animals within their limits; thus the basins between or surrounded by continuous ranges of mountains harbor faunæ differing from those on the opposite sides of the mountains. For example, the majority of the animals of the Great Basin between the Rocky Mountains and the Sierra Nevada differ from those of the Pacific slope or the prairie lands lying east of the Rocky Mountains, as the meteorological and geological features are different. The Cordilleras of South America form a barrier to the diffusion westward of Brazilian animals. Still this fact is not to be taken too literally, as the mountains are divided by valleys and rivers, which afford means of communication and an interchange of specific forms; thus certain species of animals of the Rocky Mountain plateau occur on each side of the range, as do those in the Alleghany district of the Atlantic coast. In the West Indian and especially the Hawaiian Islands, where the species of land snails are very numerous, certain forms are restricted to the deep narrow valleys, being confined to very restricted areas. So also the cold Alpine summits of the White Mountains of New Hampshire, of the Rocky Mountains, of the Alps and Scandinavian mountains harbor a few species either peculiar to those extremely limited tracts or found northward in the Arctic regions.

Deserts may act much as inland seas to separate the animals of the adjoining more fertile tracts, and they afford dwelling-places for animals which are incapable of living elsewhere. Desert faunæ have a general *facies* the world over, though the original elements out of which the faunæ have been made up may radically differ.

The distribution of plants also has much to do with that of those animals which are dependent on them for food; as a rule, the distribution of both plants and animals depends on the same physical causes.

Large rivers sometimes act as barriers, but more often, perhaps, aid in the diffusion of the smaller forms, such as insects, mollusks, and crustaceans. Different systems of rivers have distinct sets of fluviatile animals ; for example, the fishes of the Ohio and Upper Mississippi and its tributaries differ from those of the Hudson River and the New England rivers, and the latter from those draining the Southern Atlantic States. The fresh-water mussels, so abundant and characteristic of the waters of the Mississippi and its tributaries are confined to the region lying west of the Alleghanies and east of the Great Plains. The fishes and mollusks of the rivers of the Pacific slope differ from those of the scanty waters of the Great Basin.

Means of Dispersal.—The most general are the alternations of winter and summer, leading birds and mammals to migrate great distances to and from their breeding-places. Ocean-currents are most important factors in the dispersal of many marine and some land animals. By means of such great currents as the Gulf Stream, tropical animals are borne to temperate and even subarctic regions ; and, on the other hand, arctic and temperate animals are borne southward, and thus marine faunæ interdigitate and merge insensibly into one another. By this agency also new coral islands are peopled from the mainland, and peninsulas are colonized from adjoining continents or islands ; for example, the southern extremity of Florida has been visited by tropical plants and animals borne by currents and winds from the West Indies, thus lending a purely tropical aspect to the southern part, a semi-tropical fauna occupying the middle and northern part of the State.

Trade winds play an important part in scattering insects, and especially the minute forms of life ; whirlwinds and tornadoes catch up larger forms and transport them from stream to stream, pond to pond, and from lowlands to highlands, and even to Alpine summits, where may sometimes be found, under loose stones, multitudes of insects which have been borne up from below by strong gales or ascending currents of air.

The direction of the migrations of the Rocky Mountain locust seems to be mainly dependent on the direction of prevailing winds. Insects as well as birds are blown off-shore sometimes for hundreds of miles, and in this apparently haphazard way islands are, in part at least, supplied with their quota of animal life.

Great rivers, like the Missouri, Mississippi, and the Amazons, afford means of transportation from one part of a continent to another, from the interior to the seaboard, of which many fishes, insects, and especially fluviatile mollusks, avail themselves. Artificial means of crossing broad rivers are offered, to insects especially, by country-roads and bridges and railroad bridges, of which the potato-beetle and the cabbage-butterfly have fully availed themselves. The Colorado beetle has advanced steadily eastward, suddenly appearing in isolated points in New England, having apparently been transported by through grain-cars from Chicago, and has been carried to Europe in vessels. The European cabbage-butterfly introduced into Quebec spread southward into Maine along the Grand Trunk Railroad, into New York along the railroads from Montreal to New York, and then along the railroads to Washington.

Geological changes, such as the rise and submergence of the edges of continents, and also the incoming and wane of the glacial period, were still more general and fundamental means of the dispersal and rearrangement of faunæ.

Division of the Earth into Faunæ.—When we go from Maine to California we shall find that the faunistic features of the country radically change three times. Leaving the moist, temperate, forest-clad Atlantic region with its characteristic animals, and entering on the broad, treeless, dry, elevated plateau of the Rocky Mountains, we shall notice that the Atlantic fauna has been replaced almost wholly by a new and strange assemblage; and when we descend the Pacific slope of the Sierra Nevada, there will be found to be a second replacement, though much less marked than the first. Again, when we pass from Labrador to the Isthmus of Panama, we shall find several distinct faunæ, from an arctic one to a purely tropical one. If we pause at Washington and analyze the fauna of that point, we shall see that it is made up mainly of animals common to the Middle Atlantic States, with an infusion of northern and southern

Confining ourselves to the North American Continent, let us examine the distribution of life on its surface. We shall have to throw out the arctic regions, which belong with the arctic regions of Europe and Asia, to a distinct circumpolar fauna or realm, and then map out the rest of the continent into five provinces—*i.e.*, the *Canadian*, the *Alleghanian*, the *Central or Rocky Mountains*, the *Pacific or Californian*, and the *Mexican*; all of these provinces are bounded by natural geological limits and differ in temperature and moisture. While the cougar, or *Felis concolor*, is common to each one of them, and the bison and black bear range throughout the Canadian, Alleghanian, and Central provinces, there are a certain percentage of animals which are confined to each province; and on closer examination, each province, especially on the Atlantic and Pacific coasts, will be found capable of minuter subdivision into more local faunæ or *faunulæ*.

It will also be found that the animals, especially the insects, of the Atlantic province have certain elements reminding us of Northeastern Asia, while on the Pacific slope—*i.e.*, the Californian province, a few insects, shells, and crustacea, as well as the birds, remind us of European types, which are wholly wanting east of the Rocky Mountains.

On inquiring into the origin of the North American fauna, in the light of the geological history of the continent, we shall find, first, that immediately preceding the glacial period, Arctic America was peopled by a flora and fauna of which the larger proportion of the animals of the continent north of latitude 30° are probably the descendants ; and, second, that a number of species migrated northward from the South American Continent. Now, when the glacial period came in, the semi-tropical and warm temperate animals of the northern two-thirds of the continent were mostly swept out of existence ; a scanty arctic fauna took their place ; as the ice melted and retreated to its present limits, the present assemblage of temperate animals, mostly modified descendants of those originally driven south, migrated back again and colonized the region laid comparatively bare by the ice and cold of the glacial period. This is an illustration of the sweeping extinctions, recolonizations, and extended migrations of animals on our continent in former times, by which the existing relations of faunæ have been brought about. Parallel events have occurred on the Europeo-Asiatic Continent, and thus geological extinctions and widespread migrations and recolonizations have taken place ; and it is only in this way that the existing relations in the geographical distribution of animals as well as plants can be accounted for.

It should also be observed that in the beginning of things the continents were built up from north to south—such has been at least the history of the North and South American and the Europeo-Asiatic and African Continents ; and thus it would appear that north of the equator, at least, animals slowly migrated southward, keeping pace, as it were, with the growth and southward extension of the grand land masses which appeared above the sea in the Paleozoic Ages. Hence, scanty as is the arctic and temperate regions of the earth at the present time, in former ages these regions were as prolific in life as the tropics now are, the latter regions, now so vast, having all through the Tertiary and Quaternary ages been undisturbed by great geological revolutions, and meanwhile been colonized by emigrants driven down bv the incoming cold of the glacial period.

It appears, then, that each continent has had from the first its distinct assemblage of life, and thus opposing continents, such as South America and Africa, have fundamentally different faunæ, because they have had a separate geological history. Though the climate, moisture, and extent of forests of Brazil and the West Coast of Africa may, for example, be nearly identical, the animals are of a different type. At the present day, Australian trees may be transplanted to California, and flourish there, and camels from the Orient may breed in Southern California, because at the present day the climate and soil are so much alike in the two countries.

Distribution of Marine Animals.—Nearly all that has been said thus far applies to land animals. Marine species are assorted into faunæ which are nearly as well marked as terrestrial assemblages of species. The barriers restraining them within their faunal limits are the temperature of the water, this being modified more or less by the ocean-currents, the nature of the shore, whether rocky or muddy or sandy, and the nature of the sea-bottom, whether also rocky, muddy, or sandy. Many marine animals live attached to rocks and stationary pebbles, others are found only in coarse or in fine sand, while the muddy bottoms of harbors, bays, and gulfs, or the soft, deep ooze of the ocean-depths harbor a different assemblage of mud-loving species. The temperature of the water is the most important agency now in operation in the limitation of marine animals. Thus there is a tropical, north and south temperate, an arctic and probably an antarctic zone, and these are, along the shores of the different continents, subdivided into distinct faunæ. For example, along the coast of Eastern North America, the arctic or circumpolar fauna extends from the polar regions to Labrador and Newfoundland ; a second, the Acadian, to Cape Cod ; between Cape Cod and Cape Hatteras another assemblage (the Virginian) is found ; from Cape Hatteras to Southern Florida a fourth, and the Floridan peninsula belongs to the tropical regions. Along these different areas the water is of different temperatures. We also find a large proportion of circumpolar animals in the

Acadian fauna and a few in the Virginian fauna, as the Labrador or polar current passes down along the coast, bathing the New England coast north of Cape Cod, and even extending under the warm surface-water as far as New Jersey. On the other hand, the great volume of heated tropical water forming the Gulf Stream issuing from the Straits of Florida makes its influence most sensibly felt as far as Cape Hatteras, and in a diminished degree to Cape Cod, and even southern shells, etc., are found as outliers of more southern faunæ near Portland, Me., and Nova Scotia.

As we descend from the shore into deep water, the temperature becomes lower and lower the deeper we go, until we come to a stratum or zone of water about 32°–36° Fahr., where circumpolar or arctic life alone abounds. Wherever deep abysses off the coast or at the bottom of bays or gulfs occur, the water is found to be colder than elsewhere; just as when we ascend a mountain the air becomes colder, until at the Alpine summits we find an arctic temperature and fauna; thus, in the sea, increase of depth is paralleled by increase of height on land.

Usually, off the coast of the United States, north of New York, there is a distinct zone of life between high and low water, a second extending to the depth of about fifty fathoms, and a third to one hundred fathoms or over. At a depth of from one or two hundred fathoms in the Northern Atlantic, and from five hundred to one thousand fathoms in the subtropical and tropical seas, down to the deepest parts of the ocean, now known in a few points to be about five miles in depth, the water is about 32° Fahr. and the animal life is polar in its nature. The water of the ocean all over the globe, as shown by the results of the "Challenger" and other expeditions for the exploration of the sea at great depths, everywhere below a depth of one thousand fathoms, is of an arctic temperature, overlaid by the heated water of the tropics. The abysses or deeper parts of the ocean-bed support a nearly uniform assemblage of life, which may be called the deep-sea or abyssal fauna. The animals largely consist of Echinoderms, notably Crinoids, with Cœlenterates, mollusks, worms, and Crustacea, and it is an interesting fact that a few of the Echinoderms belong to genera which flourished in the Cretaceous Period ; so that in a sense the abyssal fauna may be said to be an extension in time of the Cretaceous fauna ; the physical features of the deeper parts of the sea having remained nearly the same, while the shallower parts have risen and fallen so as to undergo great changes, and have wrought corresponding changes in the life along the shores of the continents.

The following tabular view of the chief zoological faunas of the earth, proposed by Mr. J. A. Allen, is based on a study of the mammals, but will primarily apply to most land animals. The arctic realm is most distinctly characterized by the distribution of marine invertebrates, when it becomes of primary value :

I. Arctic realm, undivided.

II. North Temperate realm, with two regions, viz. :

  1. American region, with four provinces, viz.:
    a. Boreal.
    b. Eastern.
    c. Middle.
    d. Western.

  2. Europæo-Asiatic region, also with four provinces, viz. :
    a. European.
    b. Siberian.
    c. Mediterranean.
    d. Manchurian.

III. American Tropical realm, with three regions, viz.:

  1. Antillean.
  2. Central American.
  3. Brazilian.

IV. Indo-African realm, with two regions, viz. :

  1. African region, with three provinces, viz. :
    a. Eastern.
    b. Western.
    c. Southern.

2. Indian region, with two provinces, viz.:
    - *a.* Continental.
    - *b.* Insular.

V. South American Temperate realm, with two provinces, viz.:
- *a.* Andean.
- *b.* Pampean.

VI. Australian realm, with three regions, viz.:
1. Australian, with two provinces, viz.:
    - *a.* Australian.
    - *b.* Papuan.
2. Polynesian.
3. New Zealand.

VII. Lemurian realm, undivided.

VIII. Antarctic or South Circumpolar, undivided.

Migrations of Animals.—Intimately connected with zoogeography are the migrations of animals, especially birds. Nearly all the birds of the United States which breed in the central and northern portions pass southward in the autumn, and winter in the Southern States or in Central America and the West Indies. Most of the birds which breed in Northern and Central Europe fly at the approach of cold weather into Southern Europe or across the Mediterranean into Northern Africa. The causes of this regular periodical migration are probably due, primarily, to the changes of the seasons and to the want of food in the colder portion of the year, and, secondarily, to the breeding habits of birds.

The periodical migrations of fishes from deep to shoal water are connected with their breeding habits, the marine fish being in most cases compelled to spawn in rivers or in shoal-water. The migratory movements of fishes along the coast are probably connected with the presence or absence of their accustomed food.

The partial, occasional migrations of locusts depend on the undue increase in the numbers of the insects, and the consequent lack of food, while the direction of the swarms is largely dependent on the general course and force of the winds.

CHAPTER XII.

THE GEOLOGICAL SUCCESSION OF ANIMALS.

THE different systems of rocks, from the Silurian to the Quaternary or present age, contain the fossil remains of animals, which show that in the beginning the animals were, as a whole, unlike those now living, the later types becoming more and more like those now constituting the earth's fauna. The oldest set of animals, the Palæozoic, comprised species of nearly all the branches of invertebrates, with a few fishes. A large proportion of these animals belonged either to simple or to what are called *generalized* types, though some were as specialized as any invertebrates now living. Progress upward has involved the disappearance of most of the generalized types, and their replacement by more or less highly specialized types. Thus the earliest corals were mostly of the Rugose type, which were succeeded by the more complicated recent forms ; the Brachiopods or shelled worms were replaced by mollusks ; the generalized trilobites gave way to the genuine specialized shrimps and crabs ; the existing generalized king-crab, with its affinities to spiders, has survived a number of still more generalized or synthetic allies. The generalized sharks and ganoids abounded at a time when there were no bony fishes like the cod and herring. Nearly nine thousand species of bony fishes have appeared since the extinction of the earlier types of cartilaginous and mail-clad fishes. The highly specialized horse was preceded by a number of more generalized species and genera, the oldest of which approached the tapir, one of the most generalized of mammals. The succession of forms leading up to the horse is paralleled by the succession of sea-urchins and of ammonites, the older being of simpler, more generalized forms, and the later with a greater specialization or elaboration of the different, especially external, hard parts of the body.

When we ascend to the Amphibians, the reptiles and the mammals, we shall find that there has been an elaboration or working out into great detail, of the parts most used by the animal, this differentiation being more and more marked as we approach the present time; and this has been in accord with the building up of the continental masses, and the differentiation or specialization of the surface of the different continents into plains, plateaus, highlands, and mountain ranges, with their different climatic features, and the dividing up of the waters into mediterranean seas, friths, fiords, rivers, and lakes. Thus the extinction of successive faunæ all over the globe has been followed by the appearance of new sets of animals, each assemblage being adapted to the new and improved condition of things.

Having seen that the earlier forms of life were of a simpler form, though often combining the features of diverse classes and orders of animals which appeared afterward, so that Agassiz called them, in some cases, prophetic types, combining as they did characters which have been transmitted to two or more later groups, and these specially elaborated, so that such generalized or prophetic types serve as points of departure from which several series of forms have arisen—having traced the law or principle underlying the geological succession of animals, we may inquire whether this has been paralleled by the development of any one of the members of a group. That this is the case has been proved by Hyatt, who shows that the development of the individual Ammonite is paralleled by that of the geological succession of the members of the order to which it belongs. Stalked Crinoids were the style in Palæozoic ages, while free Crinoids are more abundant at the present day; and we have seen that in the individual development of the existing *Antedon*, the young is stalked at first, afterward becoming free. The young, bony fish has at first a cartilaginous skeleton and a heterocercal tail, these being characteristics of early fishes. The earlier Batrachians were tailed, the tailless toads and frogs in general appearing last, as the tadpole precedes the frog condition.

Extinction of Species.—The laws governing the extinction of animals are obscure, but we know that geological extinctions must have been due to natural causes, since the earth has at different periods evidently undergone great changes, sufficient to account for the death of such species as were unable to withstand the oscillations and changes of climate. In Palæozoic times existed multitudes of animals which, judging by their descendants of later times, belonged to old-fashioned, obsolete, useless types. They cumbered the ground, and were destroyed by the beneficent action of unerring natural laws promoting the decay and extinction of antiquated forms, and the recreation, by the laws of transmission with modification, of new, improved types, useful in their day and generation as stepping-stones to a still higher, more improved stock. That the extinction was due to causes acting primarily from without, and secondarily from within by transmission force, seems demonstrated when we take into account the destruction of life which we know took place during and at the close of the Glacial Period, when the earth was swept with glaciers, and afterward garnished with the vegetation and fresh life of the post-glacial times, and made ready for the abode of man. Thus the death of species by the action of laws that we can comprehend involves the recreation of new and improved animal forms by laws that we can at least in part, if not fully, understand.

CHAPTER XIII.

THE ORIGIN OF SPECIES.

THE extinction of species was in some cases gradual, in others sudden, so in all probability as different assemblages of life became slowly extinct new forms as slowly originated from them by genetic descent and took their places. While here and there certain species, under favorable circumstances, suddenly appeared, if we could have been there to look on, it would perhaps have been as difficult to have observed the process as it is at the present day to observe the changes going on in the relation of existing faunæ. We know, however, that changes are going on in the world of life about us, that the balance of nature is being disturbed.

The nature of the evidence tending to prove that species have originated through the agency of physical and biological laws is mainly circumstantial, there being comparatively few facts in demonstration of the theory, the direct act of transformation of one species into another under the eye of scientific experts having never been observed.

Reasoning *à priori*, we assume that organisms, both plant and animal, have been created by development from pre-existent forms because it agrees with the general course of nature. All the events in geology, as in physics and astronomy, being due to the operation of natural laws, it is reasonably supposed that the production of all the species of plants and animals from original simple forms, like the Monera or bacteria, have been the result of the action of natural law. The study of the early forms of life found in the Palæozoic strata ; the laws of the succession of types ; the correlation existing between the development of the individual and of the members of the class to which it belongs; the parallelism between the formation and differentiation of the land-masses of the globe and the successive extinctions and creations of plants and animals—all these facts, notwithstanding the imperfections of the geological record, and the fact that many of the older forms of animals were nearly as much specialized as those now living; tend strongly to prove that, on the whole, the world as it now exists has been the result of progressive development, one form coming genetically from another; the animal and plant worlds constituting two systems of blood relations, rather than sets of independent creations.

When to more special studies of those species which live in extraordinary environments, such as cave-animals, parasitic animals, brine-inhabiting animals, Alpine forms and certain deep-sea species, we add the study of rudimentary organs in adult animals, of temporary, deciduous organs in young or larval animals; when we compare the metamorphoses of some species congeneric with others which undergo no transformations; when we study the delicate balance in nature as observed in the geographical distribution of animals; the harmony in nature between species and their environment; protective coloration and resemblance in form, the relations between carnivorous and herbivorous creatures, the struggle for existence between animals, we are forced to acknowledge that the operations of nature, as a whole, tend, on the one hand, to the origination of new forms and the preservation of those which are useful, or, in other words, are in harmony with their surroundings; and, on the other hand, to the destruction of those which are incapacitated by changes in their environment for existence in what has been and now is a constantly changing, progressive world.

Again, reasoning by induction, as an actual fact we know that species vary; that hardly any two experts agree exactly as to the limitation of species;* that varieties tend to break up into races, and that no two individuals of a race are exactly alike. Where the climate and soil remain the same, the species tends to remain fixed and stable; remove the stability in the environment, or subject the individuals of a species to changes of soil and temperature, and expose it more than usual to the attacks of its natural enemies, it then begins to undergo a change. This is seen in those individuals of a species which live on the borders of lowlands and highlands, of deserts and fertile tracts, of salt and brackish water, of shallow and deep water, and of polar and temperate zones, or to the influence of alternating cold and warm weather. When, as in some cases, climatic or other agencies suddenly change, we may have species and even genera suddenly appearing, as is known to be the case in the change of one genus to another of brine shrimps when the water changes from brackish to a brine, as worked out by Schmankevitch in Russia.

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* As one of many examples, we may cite the fact that fifty-nine nominal species of the squirrels have been described as inhabiting tropical America, but lately the number has been reduced to twelve.

The struggle for existence resulting in the survival of the fittest is a fact now generally observed. The cod may deposit several millions of eggs, but of this immense number only one or a few pair of adults survive; there are probably no more codfish now than two centuries since—indeed, not as many; the eggs are devoured by different animals, the young fish, as soon as hatched, form the food of larger fish, half-grown cod serve to supply the wants of larger animals, until finally the survivors may be to the original number of eggs as one to a million. The queen bee may, during her whole life, lay more than a million of eggs, the queen white ant may lay eighty thousand eggs a day, an Aphis may be the mother of a hundred young, those hundred may each produce their centesimal offspring until the result in one season, at the end of the tenth generation, amounts to a quintillion of plant-lice; but most of these insects serve as food for other species, many die of disease and cold, until at the end of the season only one or several pairs survive to lay a few eggs, which represent the species in the winter-time.

Lastly, the variation in domestic animals, the result of the subjection of the species to influences not felt in what we call a state of nature, is an indication that animals not exposed to human interference may vary when subjected to changes in their environment. Also the fact that man can, by careful selection, breed races of horses adapted for draught, speed, or the road ; races of cows for different qualities of milk ; beeves for meat ; races of sheep for pre-eminence in the quality of their wool or mutton, or races of doves or poultry for beauty, usefulness, or other qualities ; the fact that gentleness, and generally good mental qualities, can be made to replace viciousness in horses, cattle, dogs—all these and many other facts, in the art of breeding animals known to fanciers, indicate that nature has, through the past ages, by the operation of natural laws, evolved races and species of animals which have followed constantly improving lines of development, the outcome of which are creatures the best fitted to withstand the struggle for existence, the most useful in the scheme of nature, and the most in harmony with the world about them. Progress, on the whole, therefore, has been beneficent, the best proof of which is the last product of evolution, man, the paragon of creation.

CHAPTER XIV.

PROTECTIVE RESEMBLANCE.

CLOSELY related to the foregoing subjects is the protective resemblance or "mimicry" of natural objects by which species of animals are preserved from extinction. Animals may "mimic" or imitate, or be assimilated in shape or in color to natural objects, as stones, lichens, dry bushes, the bark of trees, or portions of leaves, or entire leaves, fresh or dried, and their stems, or so closely imitate other animals which enjoy an immunity from attack as to escape notice or attacks from their enemies, and thus prolong their own lives and that of their species.

The animal is, as a rule, unconscious that it is thus protected; though there are examples, as in the case of the trap-door and other spiders, which cover their holes in such a way to avoid notice that it would appear as if they were semi-conscious or aware of what they were doing.

In the first place, we know that animals may be deceived, as is proved by the various subterfuges employed by hunters in tolling or deceiving the larger quadrupeds, the use of decoy-ducks, by which water-fowl are often thoroughly deceived and brought within reach of the gun.

The disguises worn by animals, the exquisite adaptation of the colors of their fur or feathers to their surroundings, are part of the general harmony existing throughout nature. Desert animals are rusty or light-colored; birds and insects and lizards, as well as frogs and tree-toads, which live among trees, are green; those which live among the trunks and larger branches of trees assimilate in color to the color of the bark. The cougar, which clings to the trunk of some tree, prepared to spring upon the deer passing underneath, is protected from observation by its brown neutral color, while the bars and lines of the tiger are said to resemble the lights and shades of the jungle grass in which it lies in wait for its prey. The prairie-dog, the deer, buffalo and antelope on the Western plains, are concealed by their resemblance in color to the soil, or to the bushes on its surface.

Among insects, the grasshoppers nearly always harmonize in color with the general hue of the fields in which they abound ; insects on light-colored sandy beaches are often pale, as if bleached out by the sun's rays. Alpine and arctic butterflies and moths, which have limited powers of flight, when nestling on lichen-covered rocks, are difficult to detect.

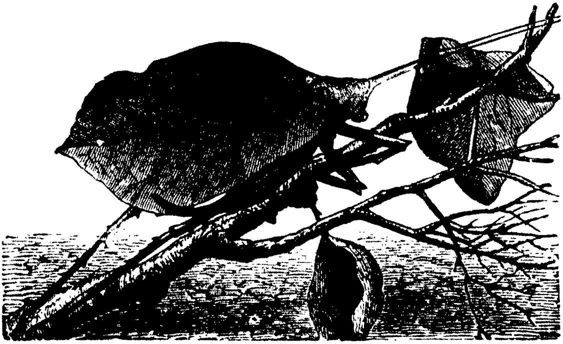

Fig. 542.—A Katydid-like form resembling a leaf.

Certain orthopterous insects resemble leaves ; such are certain katydids (Fig. 542), and especially the famous leaf-insect, *Phyllium siccifolium* Linn. (Fig. 543), which strikingly resembles a green leaf. The stick-insects (Fig. 544) also would be easily mistaken for the twigs of trees or stalks of leaves, one species (Fig. 544) representing a moss-grown twig. The under sides of the wings of our native Grapta butterflies have the color of dead leaves, so that when they are at rest they resemble a withered dry leaf. The most perfect resemblance to a leaf with its stem is the *Kallima* butterfly when setting at rest with its wings folded over its back. The caterpillars of the geometrid moths often wonderfully mimic the stems of the plants they feed upon, in color and markings, even to the warts and tubercles on their skin.

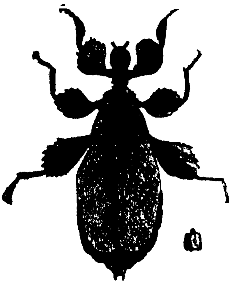

Fig. 543.—Leaf insect (*Phyllium*). Half natural size.

As an example of possibly conscious mimicry or effort at concealing their nest from the search of their enemies, may be cited the trap-door spider observed by Moggridge in Southern Europe. This spider digs its hole among moss and small ferns, and after the trap-door is made the top is covered with growing ferns, etc., transplanted by the spider, and the deception is so perfect that Mr. Moggridge found it difficult to detect the position of the closed trap, even when holding it in his hand.

Mimicry of other insects is of very frequent occurrence, certain flies resembling bees in appearance and the sounds or buzzing they make; the Syrphus flies closely imitate wasps. Fig. 545 illustrates a case observed by Belt in Nicaragua, where a wasp (*Priocnemis*) is mimicked by a hemipterous insect (*Spiniger luteocornis* Walker, the left-hand figure) in every part, even to its vibrating, brown, semi-transparent wings and its wasp-like motions. Here the bug is evidently protected by its resemblance to the wasp, for whose ferocity and sharp sting all unarmed insects have great respect.

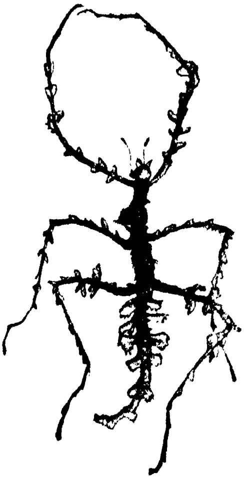

Fig. 544.—Stick insect.

Some butterflies are distasteful to birds, and there are other butterflies which have no bad taste, but closely resemble in color such species as are passed over by birds. Thus, *Danais archippus*, a common large butterfly, is not eaten by birds on account of its pungent odor, which is disagreeable to them. Another butterfly, *Limenitis disippus*, a smaller but similarly colored butterfly, which is inodorous, is supposed to be mistaken by the birds for the Danais, and thus escapes destruction.

Belt says that in Central America stinging ants are not only closely copied in form and movements by spiders, but by species of *Hemiptera* and *Coleoptera;* as stinging ants are not usually eaten by birds, this disguise is thought to protect the various forms which imitate them.

Many highly-colored caterpillars, which live exposed on the leaves of plants, are not eaten by birds, owing to their bad taste. This and other bright-colored insects may be said to hang out danger-signals to warn off hungry birds. Mr. Belt, in his "Naturalist in Nicaragua," suggests that the skunk is an example of this kind. "Its white tail, laid back on its black body, makes it very conspicuous in the dusk when it roams about, so that it is not likely to be pounced upon by any of the Carnivora mistaking it for other night-roaming animals." He also cites the case of a very poisonous, beautifully banded coral snake (*Elaps*), which is "marked as conspicuously as any noxious caterpillar with bright bands of black, yellow, and red." This author also found that while the frogs in Nicaragua are dull or green-colored, feeding at night, and all preyed upon by snakes and birds, one little species of frog, dressed in a bright liv-

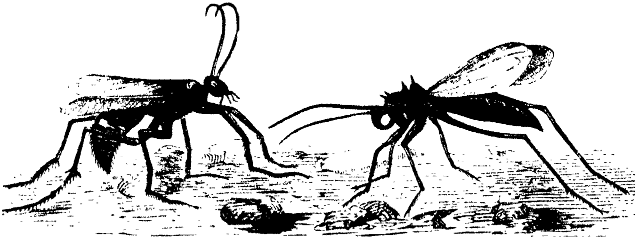

Fig. 545.—Wasp mimicked by a bug.—After Belt.

ery of red and blue, hops about in the day-time, and, as he proved by experiment, is thoroughly distasteful to fowls and ducks.

We have seen that many animals resemble externally those above them in the scale of life; in the synthetic or generalized types from which the more specialized forms have probably originated, there are characters which cause them to resemble more recent, new-fashioned types. It is possible that in many cases the older types, doomed as they were to destruction, have had their existence prolonged by their protective resemblance to modern types.

For example, the *Neuroptera* as a group are geologically of high antiquity; owing to geological extinction, but few species, compared with those of other orders, have survived; and those which are now living often resemble members of higher, more recent orders. The inference is, then, that the mimickers have survived by reason of their resemblance to the more abundant forms which appeared, as the more old-fashioned types were waning or dying out.

Certain Brazilian species of the lepidopterous family, *Zygænidæ* and *Bombycidæ*, mimic in form and coloration certain butterflies, especially the *Heliconidæ*, which abound in Brazil. The former groups are evidently the older geologically, as there are wide gaps between the genera; and the indications are that these butterfly-like moths have likewise, from their resemblance to the more abundant *Heliconidæ,* been preserved. It thus appears that protective mimicry may be an important factor in the preservation of species.

CHAPTER XV.

INSTINCT AND REASON IN ANIMALS.

We have seen that animals have organs of sense, of perception, in many cases nearly as highly developed as in man, and that in the mammalia the eyes, ears, organs of smell and touch differ but slightly from those of our own species; also that the brain and nervous system of the higher mammals closely approximate to those of man. We know that all animals are endowed with sufficient intelligence to meet the ordinary exigencies of life, and that some insects, birds, and mammals are able, on occasion, to meet extraordinary emergencies—in other words, to rise with the occasion. These occurrences indicate that what usually goes by the name of "instinct" is more or less pliable, unstable; that animals are in a limited degree free agents, with powers of choice. Moreover, those naturalists who observe most closely and patiently the habits of animals do not hesitate to state their belief that animals, and some more than others, possess reasoning powers which differ in degree rather than in kind from the purely intellectual acts of man.

As a matter of not infrequent observation, animals exercise the power of choice, they select this or that kind of food, prefer this or that kind of odor, and have their likes and dislikes to certain persons, and all this aside from mere physical stimulation of the senses. Moreover, animals are subject to the passions, they show anger, even when not hungry or under the domination of the reproductive instincts; their sounds express dissatisfaction or contentment. Indeed, many facts could be stated showing that animals not only have feelings, intelligence, and volition, but are possibly, in a very slight degree, self-conscious. The fact that animals exercise discrimination in the selection of food, in the choice of a flower or object of one color in preference to another, in perceiving likeness or unlikeness in two objects, indicates that they can exercise the power of intelligent discrimination, as has been said by Mr. G. H. Lewes :* "When there is no alternative open to an action it is impulsive ; when there is, or originally was, an alternative, the action is instinctive ; where there are alternatives which may still determine the action, and the choice is free, we call the action intelligent."

Indeed, animals have the principle of similarity strongly developed. It is the bond that holds together the social organizations of such insects as live in colonies, and such fish, birds, or mammals as go in schools, flocks, or herds. Were it not for this mental quality some species would tend to die out.

Animals possess memory, which consists in storing up in the mind the results of external impressions, so that they are enabled to perceive the points of resemblance or difference between two objects, after having been out of sight of them for a greater or less length of time. Bain defines memory, acquisition or retention, as "being the power of continuing in the mind impressions that are no longer stimulated by the same agent, and of recalling them afterward by purely mental forces."

With the aid of memory, birds make their migrations, bees and ants find their way back to their nests. As we have elsewhere said, "No automaton could find its way back to a point from which it had once started, however well the machine had been originally wound up. Nor does the common notion of an inflexible instinct meet the case. Memory is often due to a repetition of certain experiences, and experiences lay the foundation for instinctive acts ; it is the sum of these inherited experiences which make up the total which passes under the name of instinct."†

* Article on Instinct in Nature, April 10th, 1873.

† Half Hours with Insects, p. 374.

It would appear, then, that animals have in some slight degree what we call *mind,* with its threefold divisions of the sensibilities, intellect, and will. When we study animals in a state of domestication, especially the dog or horse, we know that they are capable of some degree of education, and that they transmit the new traits or habits which they have been taught to their offspring ; so that what in the parents were newly acquired habits become in the descendants instinctive acts. We are thus led to suppose that the terse definition of instinct by Murphy, that it is " the sum of inherited habits," is in accordance with observed facts. Indeed, if animals have sufficient intelligence to meet the extraordinary emergencies of their lives, their daily, so-called instinctive acts, requiring a minimum expenditure of mental energy, may have originated in previous generations, and this suggests that the instincts of the present generation may be the sum total of the inherited mental experiences of former generations.

Descartes believed that animals are automata. Lamarck expressed the opinion that instincts were due to certain inherent inclinations arising from habits impressed upon the organs of the animals concerned in producing them.

Darwin does not attempt any definition of instinct ; but he suggests that " several distinct mental actions are commonly embraced by this term," and adds that " a little dose, as Pierre Huber expresses it, of judgment or reason often comes into play, even in animals low in the scale of nature." He indicates the points of resemblance between instincts and habits, shows that habitual action may become inherited, especially in animals under domestication ; and since habitual action does sometimes become inherited, he thinks it follows that " the resemblance between what originally was a habit and an instinct becomes so close as not to be distinguished." He concludes that, by natural selection, slight modifications of instinct which are in any way useful accumulate, and thus animals have slowly and gradually, " as small consequences of one general law," acquired, through successive generations, their power of acting instinctively, and that they were not suddenly or specially endowed with instincts.

Rev. J. J. Murphy, in his work entitled "Habit and Intelligence," seems to regard instinct as the sum of inherited habits, remarking that "reason differs from instinct only in being conscious. Instinct is unconscious reason, and reason is conscious instinct." This seems equivalent to saying that most of the instincts of the present generation of animals is unconscious automatism, but that in the beginning, in the ancestors of the present races, instincts were more plastic than now, such traits as were useful to the organism being preserved and crystallized, as it were, into the instinctive acts of their lives. This does not exclude the idea that animals, while in most respects automata, occasionally perform acts which transcend instinct; that they are still modified by circumstances, especially those species which in any way come in contact with man; are still in a degree free agents, and have unconsciously learned, by success or failure, to adapt themselves to new surroundings. This view is strengthened by the fact that there is a marked degree of individuality among animals. Some individuals of the same species are much more intelligent than others, they act as leaders in different operations. Among dogs, horses, and other domestic animals, those of dull intellect are led or excelled by those of greater intelligence, and this indicates that they are not simply automata, but are also in a degree, or within their own sphere, free agents.

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GLOSSARY.

Abdomen. In mammals the part of the trunk below or behind the thorax ; in insects the third region of the body, or hind body.

Aberrant. Departing from the regular or normal type.

Aboral. Opposite the oral or mouth-region.

Acuminate. Ending in a prolonged point.

Alveolus. A hollow cavity forming the socket in the jaw of vertebrates for the teeth.

Ambulacrum (Lat. from *ambulare*, to walk, a garden-walk). The perforated space or area in the shell of the sea-urchin or the arm of a star-fish, through which the foot-tubes or ambulacral feet are protruded.

Ametabolic (Gr. *a*, without ; *metabole*, change). Referring to insects and other animals which do not undergo a metamorphosis.

Amorphous (Gr. *a*, privitive ; *morphe*, form). Without a definite figure ; shapeless ; especially applicable to sponges.

Amphicœlous (Gr. *amphi ; koilos*, hollow). Applied to vertebræ which are doubly concave, or hollow at both ends.

Anastomosing. Inosculating or running into each other like veins.

Anchylosis. The growing together of two bones so as to prevent motion between them.

Annulate. When a leg or antenna is surrounded by narrow rings of a different color.

Aplacental. Referring to those mammals in which the embryos are destitute of a placenta.

Apodous. Footless.

Apterous (Gr. *a*, without ; *pteron*, wing). Destitute of wings.

Aquiferous (Lat. *aqua*, water ; I carry). Applied to the water-carrying or water-vascular system of the sponges, etc.

Areolate. Furnished with small areas ; like a net-work.

Aristate. Furnished with a hair.

(Gr. *a*, without ; *arthros*, a joint ; *pous*, *podos*, foot). Those Articulata with jointed feet.

Articulata (Lat. *articulus*, diminutive of *artus*, a joint). Cuvier's subkingdom of worms, crustacea and insects.

Artiodactyla (Gr. *artios*, even ; *daktulos*, finger or toe). Those Ungulates with an even number of toes, as the ox.

Asexual. Applied to animals,

especially insects, in which the ovaries or reproductive organs are imperfectly developed; and which produce eggs or young by budding.

Aurelia. Old term for the pupa of an insect.

Auricle (Lat. *auricula*, a little ear). One of the cavities of the heart of mollusks and vertebrates.

Azygos (*a*, without; *zugon*, a yoke, a pair). An organ, such as a nerve or artery, situated in the middle line of a bilaterally symmetrical animal, which has therefore no fellow.

Blastoderm (*blastos*, a bud or sprout; *derma*, skin). The outer layer of the germ-cells of the embryo.

Bifid. Divided into two parts; forked.

Branchia. A gill or respiratory organ of aquatic animals.

Buccal. Relating to the mouth or cheeks.

Bullate. Blistered.

Caducibranchiate (Lat. *caducus*, falling off; Gr. *bragchia*, gills). Applied to those *Batrachia* in which the gills become absorbed before adult life.

Calcarated. Armed with spurs.

Calyx. A little cup; often applied to the body of a Crinoid.

Capitate. Ending in a head or knob.

Chela. The terminal portion of a limb with a movable lateral part, like the claw of a crab; as in the chelate maxilla of the scorpion.

Chiasma (Gr. *chiasma*, a crossing.) The commissure of the optic nerves in most vertebrates.

Chitin (Gr. *chiton*, a tunic). The horny covering of insects, etc.

Chyle (Gr. *chulos*, juice). The milky fluid resulting from the action of the digestive fluids on the food or chyme.

Chyme (Gr. *chumos*, juice). The acid, partly fluid or partly digested food, produced by the action of the gastric juice on the food.

Cilium (pl. *cilia*). Microscopic filaments attached to cells, usually within the body, and moving usually rhythmically,

Cœcal. Ending blindly or in a cul-de-sac.

Cœcum. A blind sac; usually applied to one or more appendages of the digestive canal.

Cœnenchyma (Gr. *koinos*, common; *chumos*, chyme or juice). Applied in polyps to the coral mass containing the chymiferous or nutritive canals connecting the different polyps.

Commissure. The nerves connecting two ganglia.

Concolorous. Of the same color as another part.

Condyle (Gr. *kondulos*, a knuckle). The articular surface of a bone, especially of the occiput.

Cortical. Relating to the cortex or inner skin; external as opposed to medullary.

Costal (Lat. *costa*, a rib). Relating to the ribs.

Cribriform (Lat. *cribrum*, a sieve; *forma*, form). With perforations like those of a sieve.

Crop. A partial dilatation of the gullet or œsophagus, the ingluvies; in many insects the fore stomach or proventriculus.

Cuticle. The outermost layer of the integument.

Dentate. Furnished with teeth.

Didelphia (Gr. *dis*, two, or double; *delphus*, womb). The subclass of Marsupials.

Differentiation. The specialization or setting apart of special organs for special work, as the specialization of the hand of man from the fore-foot of other mammals; also applied to the special development during embryonic life of parts adapted for peculiar or special functions.

Dimidiate. Half round.

Diœcious (Gr. *dis*, two; *oikos*, house). With distinct sexes.

Diptera (Gr. *dis*, two; *pteron*, wing). Two-winged flies; an order of insects.

Diverticulum. An offshoot from a vessel or from the alimentary canal.

Ecdysis (Gr. *ekdusis*, casting off). The process of casting the skin; moulting.

Echinodermata (Gr. *echinos*, a hedgehog or urchin; hence applied to the sea-urchin; and *derma*, skin). The fourth subkingdom of animals.

Elasmobranchii (Gr. *elasma*, a strap; *bragchia*, gill). The sharks and rays.

Elytra (Gr. *elutron*, a sheath). The fore-wings of beetles, serving to cover or sheathe the hind wings.

Epistoma. That part of the face of flies situated between the front and the labrum.

Equilateral. Having the sides equal, as in Brachiopod shells.

Equivalve. Applied to shells like the clams and most Lamellibranchs, which are composed of two equal pieces or valves.

Protruded, opposed to enclosed.

Exuvium. Cast-off skin.

s (Lat. *fissus*, cleft; *pario*, to bring forth). Applied to a form of asexual generation where the parent splits into two parts, each part becoming a new individual.

Gemmiparous (*gemma*, bud; *pario*, to bring forth). Applied to a form of asexual generation where new individuals arise as buds from the body of the parent.

Glabrous. Smooth; opposed to hairy; downy, villous.

Glaucous. Bluish green or gray.

Hæmal (Gr. *haima*, blood). Connected with the blood-vessels or heart.

Halteres (Gr. *halteres*, poisers). Balancers; the rudimentary hind wings of Diptera.

Haustellate. Furnished with a proboscis so as to take food by suction.

Hemiptera (Gr. *hemi*, half; *pteron*, wing). An order of insects with the fore-wings partly opaque, hence called hemelytra.

Hermaphrodite (Gr. *Hermes*, Mercury; *Aphrodite*, Venus). Any animal having the organs of both sexes, usually the ovary and testes, combined in the same individual.

Hexapodous. Provided with six feet.

Hymenoptera (Gr. *humen*, hymen, or membrane; *pteron*. An order of insects with two pairs of membranous wings.

Hyoid (Gr. Υ, *eidos*, resemblance). A bone in man named from resembling the letter U; its form being different in other vertebrates: also called *os linguæ*, from its supporting the tongue.

Imago. The final or fourth, winged and adult state of insects.

Inequilateral Having the two ends unequal, as in the clam, quohog, and most Lamellibranch shells.

Inequivalve. With one valve differing in size or shape from the other, as in the oyster or Brachiopod shells.

Irrorated. Freckled; sprinkled with atoms.

Lamellibranchiata (Lat. *lamella*, a leaf or sheet; *branchia*, gill). A class of mollusks with large leaf-like gills.

Larva (Lat. *larva*, a mask). The second stage of the insect, a caterpillar, grub, or maggot.

Lumbar (Lat. *lumbus*, a loin). Connected with the loins.

Monœcious (Gr. *monos*, single; *oikos*, house). With the sexual glands, etc., united in the same individual.

Nematocyst (Gr. *nema*, a thread; *kustis*, a bladder). The nettling, stinging organs or thread-cells or lasso-cells of the jelly-fishes and polyps, etc.

Neuroptera (Gr. *neuron*, a cord; *pteron*, wing). The order of net-veined insects.

Nidamental. Referring to a nest, or egg-sac.

Notochord (Gr. *noton*, back; *chorde*, a string), or *chorda dorsalis*. The primitive support of the body of vertebrate embryos, larval ascidians, and the backbone of the lancelet and lampreys.

Obtected. Covered; concealed.

Odontophore (Gr. *odous*, a tooth; *phero*, I carry). The so-called tongue or lingual ribbon of the higher mollusks.

Œsophagus (Gr. *oisos*, a reed; *phagein*, to eat). The gullet.

Operculum (Lat. *operio*, to cover). In fishes one or more bones covering the gills; in Gastropod Mollusks a horny plate or solid limestone mass closing the orifice of shells.

Opisthocœlous (Gr. *opisthen*, behind; *koilos*, hollow). Those vertebrates with bodies hollow behind and convex in front.

Oral. Related to the mouth.

Ornithodelphia (Gr. *ornis*, bird; *delphus*, womb). The sub-class of mammals and order *Monotre-*

Orthoptera (Gr. *orthos*, straight; *pteron*, wing). The order of insects with straight narrow fore-wings, as the grasshoppers.

Ostracoda (Gr. *ostracodes*, shelled). A group of shelled crustacea.

Otoliths (Gr. *ous*, ear; *lithos*, stone). Small bones suspended in the internal ear of fishes, or concretions in the auditory sacs of invertebrates.

OVIPAROUS (Lat. *ovum*, an egg; *pario*, I bring forth). Applied to animals bringing forth eggs instead of living, active young.

OVIPOSITOR (Lat. *ovum*, an egg; *pono*, I place). An organ in insects homologous with the sting, by which eggs are deposited in solid substances.

OVISAC. A sac or bag-like membrane attached to the parent, and containing eggs.

OVO-VIVIPAROUS (Lat. *ovum*, an egg; *vivus*, alive; *pario*, I bring forth). Applied to such animals as retain their eggs in the body until they are hatched.

PALLIUM (Lat. a cloak). The mantle or body-wall of mollusks, which secretes the shell; adj. pallial.

PARENCHYMA (Gr. *paregchuma*, from *para*, *en*, *chuo*, something poured in besides). Applied to the proper substance of viscera, excluding connective tissue, blood-vessels, and other accessory parts.

PELAGIC. Living on the high seas, away from the coast; in mid-ocean.

PERISOME (Gr. *peri*, around; *soma*, body). In Crinoids the oral region of the cup or body.

PERRENNIBRANCHIATA (Lat. *perennis*, perennial; *branchia*, gill). Those Batrachia which retain their gills throughout life.

PERISSODACTYLA (Gr. *perissos*, uneven; *daktulos*, finger). Those Ungulates with an uneven number of toes, as the horse.

PERITONEUM (Gr. *peri*, around; *teino*, I stretch). The membrane lining the abdominal walls and covering the enclosed viscera.

PERIVISCERAL (Gr. *peri*, around; Lat. *viscera*, the internal organs, especially of the abdominal cavity). The body-cavity containing the alimentary canal with its outgrowths.

PICEOUS. Pitchy; the color of pitch; shining reddish black.

PILOSE. Clothed with pile, or dense short down.

PLEXUS (Lat. a knot). Applied to a knot-like mass of nerves or blood-vessels.

POLYPIDE or POLYPITE. The separate animals of a Hydrozoon.

PREORAL. In front of the mouth.

PROCESS. A projection; used chiefly in osteology.

PROCŒLOUS (Gr. *pro*, front; *koilos*, hollow). Those vertebræ concave or hollow in front.

PROTOPLASM (Gr. *protos*, first; *plasma*, from *plasso*, I mould). The albuminous, elementary matter forming cells and the body-substance of *Protozoa*.

PROXIMAL (Lat. *proximus*, next). The fixed end of a limb, bone or appendage; that nearest the body; opposed to *distal*, the farther end.

PSEUDOPODIA (Gr. *pseudes*, false; *podes*, feet). The temporary processes sent out from the bodies of *Protozoa*.

PTEROPODA (Gr. *pteron*, wing; *podes*, feet). A class of pelagic mollusks.

Coated with very fine hairs.

Marked with numerous small impressed dots.

PUPA (Lat. a doll). The third or

usually quiescent, chrysalis stage of insects.

Ratitæ (Lat. *ratis*, a raft). A division of birds with a keelless, raft or punt-like sternum.

Rhizopoda (Gr. *riza*, root; *pous*, *podos*, foot). The root-footed *Protozoa*.

Rotifera (Lat. *rota*, a wheel; *fero*, I bear). An order of crustacea with a pair of ciliated vela in motion, resembling wheels.

Sarcode (Gr. *sarx*, flesh; *odos*, way). Equivalent and earlier term for protoplasm.

Scabrous. Rough like a file, with small raised dots.

Setaceous (Lat. *seta*, a bristle). Bristle-like.

Spiracle (Lat. *spiro*, to breathe). The lateral breathing pores of insects.

Stigmata (Gr. *stigma*, a mark). A synonym of spiracle.

Stolon (Lat. *stolo*, a shoot springing from the root of a plant). Applied to the root-like creeping growths of polyps and other Cœlenterates.

Strepsiptera (Gr. *strephis*, a twist; *pteron*, wing). A group of beetles, whose minute front wings appear as if twisted.

Strobila (Gr. *strobilos*, a fir cone). The chain of zooids of a larval medusa; the chain of proglottides of a tape-worm.

Suture. A seam or impressed line between the bones of the skull or parts of the crust of an Arthropod.

Symphysis (Gr. *sumphusis*, a growing together). The union of two bones.

Telson (Gr. *telson*, from *telos*, end). The rudimentary terminal segment of the abdomen of Arthropods.

Teneral. A state of the Neuropterous imago after exclusion from the pupa, in which it has not fully completed its coloring, clothing, etc.

Tentaculum (Lat. *tento*, I touch). A feeler or tentacle.

Tergum (Lat. back). The dorsal region of Arthropods.

Test (Lat. *testa*, a shell). The thickened integument of *Tunicata*.

Testaceous. Dull red; brick color.

Thorax (Gr. *thorax*, a breastplate). The chest in vertebrates; the middle body in insects and some crustacea.

Thysanura (Gr. *thusanoi*, fringes; *oura*, tail). The lowest order of insects.

Tomentose. Covered with fine matted hairs.

Trabeculæ (cranii), dim. of *trabs*, a beam. Applied to the longitudinal cartilaginous bars of the fore-part of the head of vertebrate embryos.

Trachea (Gr. *tracheia*, the rough windpipe). The respiratory tube in vertebrates; the air-tube of Tracheate insects.

Trematoda (Gr. *trema*, a pore or hole). An order of worms.

Truncated. Cut squarely off; docked.

Tuberculose. Covered with tubercles.

Tunicata (Lat. *tunica*, a cloak). The class of worms called Ascidians.

UMBO (Lat. the boss of a shield). The beak of a Lamellibranchiate shell.

UNGULATA (Lat. *ungula*, a hoof). The order of hoofed mammals.

URODELA (Gr. *oura*, tail ; *delos*, visible). The tailed Batrachians.

VACUOLE (Lat. *vacuus*, empty). The little cavities in the bodies of *Protozoa*.

VENTRAL. Applied to the under side of the abdomen, or of the body of invertebrates.

VENTRICLE (Lat. *ventriculus*, diminutive of *venter*, belly). One of the cavities of the heart.

VERRICULATE. With thick-set tufts of parallel hairs.

VERRUCOSE. Covered with wart-like prominences.

VERTEBRA (Lat. *verto*, I turn). One of the bones of the spinal column or backbone.

VERTICILLATE. Placed in whirls.

VESICLE (Lat. *vesica*, a bladder). A little sac, bladder, or cyst.

VISCERA (Lat. *viscus*). The internal organs of the body.

VIVIPAROUS (Lat. *vivus*, alive ; and *pario*, I bring forth). Applied to animals which bring forth their young alive.

(Gr. *zoön*, animal ; *eidos*, form). The highly specialized organs of such animals as the Hydroids, and other compound forms which have a marked individuality, and which might be mistaken for genuine individuals.

ZOOPHYTE (Gr. *zoön*, animal ; *phuton*, plant). Applied to the plant-like polyps, sertularians, and sponges.

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